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French standard

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Ductile iron pipes, fittings, accessories
and their joints for water pipelines

Requirements and test methods

F : Tuyaux, raccords et accessoires en fonte ductile et leurs assemblages
pour canalisations d'eau — Prescriptions et méthodes d'essai

D : Rohre, Formstücke, Zubehörteile aus Gusseisen und ihre Verbindungen
für Wasserleitungen — Anforderungen und Prüfverfahren

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Replaces the approved standard NF EN 545 dated August 2002.

Correspondence

The European standard EN 545:2006 has the status of French standard.

Analysis

This document specifies the requirements and associated test methods applicable to ductile iron pipes, fittings, accessories and their joints for the construction of pipelines as well as requirements for materials, dimensions and tolerances, mechanical properties and standard coatings of ductile iron pipes and fittings. It also gives performance requirements for all components including joints. Joint design and the geometry of joint rings are not part of the scope of application of this document.

Descriptors

Technical International Thesaurus: pipe units, water pipelines, cast iron products, pipes: tubes, pipe fittings, accessories, definitions, dimensions, dimensional tolerances, coatings, thickness, tests, tension tests, hardness tests, fluid-tightness tests, tables (data).

Modifications

With respect to document replaced, revision of the standard.

Corrections



National foreword

References to French standards

The correspondence between the standards figuring in the clause "Normative references" and the identical French standards is as follows:

EN 196-1 : NF EN 196-1 (classification index: P 15-471-1)

EN 197-1 : NF EN 197-1 (classification index: P 15-101-1)

EN 681-1 : NF EN 681-1 (classification index: T 47-305-1)

EN 805 : NF EN 805 (classification index: P 41-010)

EN 1092-2 : NF EN 1092-2 (classification index: E 29-200-2)

EN 10002-1 : NF EN 10002-1 (classification index: A 03-001)

EN ISO 4016 : NF EN ISO 4016 (classification index: E 25-115-1)

EN ISO 4034 : NF EN ISO 4034 (classification index: E 25-402)

EN ISO 6506-1 : NF EN ISO 6506-1 (classification index: A 03-152-1)

EN ISO 7091 : NF EN ISO 7091 (classification index: E 25-528)

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English Version

**Ductile iron pipes, fittings, accessories and their joints for water
pipelines - Requirements and test methods**

Tuyaux, raccords et accessoires en fonte ductile et leurs
assemblages pour canalisations d'eau - Prescriptions et
méthodes d'essai

Rohre, Formstücke, Zubehörteile aus duktilem Gusseisen
und ihre Verbindungen für Wasserleitungen -
Anforderungen und Prüfverfahren

This European Standard was approved by CEN on 11 October 2006.

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Foreword

This document (EN 545:2006) has been prepared by Technical Committee CEN/TC 203 “Cast iron pipes, fittings and their joints”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2007, and conflicting national standards shall be withdrawn at the latest by May 2007.

This document supersedes EN 545:2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This standard is in conformity with the general requirements already established by CEN/TC 164 in the field of water supply.

In respect of potential adverse effects on the quality of water intended for human consumption, caused by the product covered by this standard:

- this standard provides no information as to whether the product may be used without restriction in any of the member states of the EU or EFTA;
- it should be noted that, while awaiting the adoption of verifiable European criteria, existing national regulations concerning the use and/or the characteristics of this product remain in force.

EN 545:2006 (E)**1 Scope**

This European Standard specifies the requirements and associated test methods applicable to ductile iron pipes, fittings, accessories and their joints for the construction of pipelines:

- to convey water (e. g. potable water);
- with or without pressure;
- to be installed below or above ground.

This standard is applicable to pipes, fittings and accessories which are:

- manufactured with socketed, flanged or spigot ends;
- normally delivered externally and internally coated;
- suitable for fluid temperatures between 0 °C and 50 °C, excluding frost.

This standard covers pipes, fittings and accessories cast by any type of foundry process or manufactured by fabrication of cast components, as well as corresponding joints, in a size range extending from DN 40 to DN 2 000, inclusive.

This standard specifies requirements for materials, dimensions and tolerances, mechanical properties and standard coatings of ductile iron pipes and fittings. It also gives performance requirements for all components including joints. Joint design and gasket shapes are outside the scope of this standard.

NOTE In this standard, all pressures are relative pressures, expressed in bars (100 kPa = 1 bar).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 196-1, *Methods of testing cement — Part 1: Determination of strength*

EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 681-1, *Elastomeric seals — Materials requirements for pipe joint seals used in water and drainage applications — Part 1: Vulcanized rubber*

EN 805, *Water supply — Requirements for systems and components outside buildings*

EN 1092-2, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated — Part 2: Cast iron flanges*

EN 10002-1, *Metallic materials — Tensile testing — Part 1: Method of test at ambient temperature*

EN ISO 4016, *Hexagon head bolts — Product grade C (ISO 4016:1999)*

EN ISO 4034, *Hexagon nuts — Product grade C (ISO 4034:1999)*

EN ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method (ISO 6506-1:2005)*

EN ISO 7091, *Plain washers — Normal series — Product grade C (ISO 7091:2000)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

ductile iron

cast iron used for pipes, fittings and accessories in which graphite is present substantially in spheroidal form

3.2

pipe

casting of uniform bore, straight in axis, having socket, spigot or flanged ends, except for flanged-socket pieces, flanged-spigot pieces and collars which are classified as fittings

3.3

fitting

casting other than a pipe which allows pipeline deviation, change of direction or bore

NOTE flanged-socket pieces, flanged spigot pieces and collars are also classified as fittings

3.4

accessory

any casting other than a pipe or fitting which is used in a pipeline;

NOTE 1 for example:

- glands and bolts for mechanical flexible joints (see 3.13);
- glands, bolts and locking rings for restrained flexible joints (see 3.14);
- pipe saddles for service cock connections;
- adjustable flanges and flanges to be welded or screwed.

NOTE 2 Valves of all types are not covered by the term accessory.

3.5

flange

flat circular end of a pipe or fitting extending perpendicular to its axis, with bolt holes equally spaced on a circle

NOTE A flange can be fixed (e.g. integrally cast or welded) or adjustable; an adjustable flange comprises a ring, in one or several parts assembled together, which bears on an end joint hub and can be freely rotated around the pipe axis before jointing.

3.6

spigot

male end of a pipe or fitting

3.7

spigot end

maximum insertion depth of the spigot plus 50 mm

3.8

socket

female end of a pipe or fitting to make the connection with the spigot of the next component

3.9

gasket

sealing component of a joint

3.10

joint

connection between the ends of two pipes and/or fittings in which a gasket is used to effect a seal

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3.11

flexible joint

joint which permits significant angular deflection both during and after installation and which can accept a slight offset of the centreline

3.12

push-in flexible joint

flexible joint assembled by pushing the spigot through the gasket in the socket of the mating component

3.13

mechanical flexible joint

flexible joint in which sealing is obtained by applying pressure to the gasket by mechanical means, e.g. a gland

3.14

restrained flexible joint

flexible joint in which a means is provided to prevent separation of the assembled joint

3.15

flanged joint

joint between two flanged ends

3.16

nominal size (DN)

alphanumeric designation of size for components of a pipework system, which is used for reference purposes. It comprises the letters DN followed by a dimensionless whole number which is indirectly related to the physical size, in millimetres, of the bore or outside diameter of the end connections

[EN ISO 6708:1995]

3.17

nominal pressure (PN)

alphanumeric designation used for reference purposes related to a combination of mechanical and dimensional characteristics of a component of a pipework system. It comprises the letters PN followed by a dimensionless number

[EN 1333:2006]

NOTE All equipment of the same nominal size DN designated by the same PN number have compatible mating dimensions.

3.18

leak tightness test pressure

pressure applied to a component during manufacture in order to ensure its leak tightness

3.19

allowable operating pressure (PFA)

maximum hydrostatic pressure that a component is capable of withstanding continuously in service

[EN 805:2000]

3.20

allowable maximum operating pressure (PMA)

maximum pressure occurring from time to time, including surge, that a component is capable of withstanding in service

[EN 805:2000]

3.21

allowable test pressure (PEA)

maximum hydrostatic pressure that a newly installed component is capable of withstanding for a relatively short duration, in order to insure the integrity and tightness of the pipeline

[EN 805:2000]

NOTE This test pressure is different from the system test pressure (STP), which is related to the design pressure of the pipeline and is intended to ensure its integrity and leak tightness ; see also A.1.

3.22**diametral stiffness of a pipe**

characteristic of a pipe which allows it to resist ovalization under loading when installed

3.23**performance test**

proof of design test which is done once and is repeated only after change of design

3.24**length**

effective length of a pipe or fitting, as shown on Figure 4 for pipes and on Figures 5 to 21 for fittings

NOTE For flanged pipes and fittings, the effective length L (l for branches) is equal to the overall length. For socketed pipes and fittings, the effective length L_u (l_u for branches), is equal to the overall length minus the maximum spigot insertion depth as given in the manufacturer's catalogues.

3.25**deviation**

design length allowance with respect to the standardized length of a pipe or a fitting

3.26**ovality**

out of roundness of a pipe section;

NOTE it is equal to:

$$100 \left(\frac{A_1 - A_2}{A_1 + A_2} \right) \quad (1)$$

where:

A_1 is the maximum axis, in millimetres;

A_2 is the minimum axis, in millimetres.

4 Technical requirements**4.1 General****4.1.1 Ductile iron pipes and fittings**

Nominal sizes, thickness classes, lengths and coatings are specified in 4.1.1, 4.2.1, 4.2.3, 4.4 and 4.5 respectively. When, by agreement between manufacturer and purchaser, pipes and fittings with different wall thickness classes, lengths and/or coatings and other types of fittings than those given in 8.3 and 8.4, are supplied with reference to this standard, they shall comply with all the other requirements of this standard.

NOTE 1 Other types of fittings include angle branches, tees and tapers with other combinations DN x dn, draining tees, ...

The standardized nominal sizes DN of pipes and fittings are as follows: (see EN 805) 40, 50, 60, 65, 80, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1 000, 1 100, 1 200, 1 400, 1 500, 1 600, 1 800, 2 000.

The allowable pressures of ductile iron pipes and fittings shall be as given in Annex A.

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NOTE 2 Annexes B and C give respectively the longitudinal bending resistance and the diametral stiffness of ductile iron pipes.

NOTE 3 When installed and operated under the conditions for which they are designed (see Annexes D, E and G), ductile iron pipes, fittings, accessories and their joints maintain all their functional characteristics over their operating life, due to the constant material properties, to the stability of their cross section and to their design with high safety factors.

4.1.2 Surface condition and repair

Pipes, fittings and accessories shall be free from defects and surface imperfections which can lead to non-compliance with Clause 4 and Clause 5.

When necessary, pipes and fittings may be repaired, for example by welding, in order to remove surface imperfections and localized defects which do not extend through the entire wall thickness, provided that :

- the repairs are carried out according to the manufacturer's written procedure;
- the repaired pipes and fittings comply with all the requirements of Clause 4 and Clause 5.

4.1.3 Types of joints and interconnection**4.1.3.1 General**

Rubber gasket materials shall comply with the requirements of EN 681-1, type WA. When materials other than rubber are necessary (e.g. for flanged joints), they shall comply with the appropriate European Standard or, where no European Standard exists, the appropriate International Standard.

4.1.3.2 Flanged joints

Flanges shall be constructed in such a way that they can be attached to flanges whose dimensions and tolerances comply with EN 1092-2. This ensures interconnection between all flanged components (pipes, fittings, valves,...) of the same PN and DN and adequate joint performance.

Bolts and nuts shall comply as a minimum with the requirements of EN ISO 4016 and EN ISO 4034, grade 4.6. When applicable, washers shall comply with EN ISO 7091.

Although it does not affect interconnection, the manufacturer shall state in his catalogues whether his products are normally delivered with fixed flanges or adjustable flanges.

NOTE Flange gaskets can be one of those given in EN 1514.

4.1.3.3 Flexible joints

Pipes and fittings with flexible joints shall comply with 4.2.2.1 for their spigot external diameter DE and their tolerances. This offers the possibility of interconnection between components equipped with different types of flexible joints. In addition, each type of flexible joint shall be designed to fulfil the performance requirements of Clause 5.

NOTE 1 For interconnection with certain types of joints operating within a different tolerance range on DE, the manufacturer's guidance should be followed as to the means of ensuring adequate joint performance at high pressures (e.g. measurement and selection of external diameter).

NOTE 2 For interconnection with existing pipelines which can have external diameters not in compliance with 4.2.2.1, the manufacturer's guidance should be followed as to the appropriate means of interconnection (e.g. adaptors).

4.1.4 Materials in contact with water intended for human consumption

Ductile iron pipes, fittings and their joints include several materials given in this standard. When used under the conditions for which they are designed, in permanent or in temporary contact with water intended for human consumption, ductile iron pipes, fittings and their joints shall not change the quality of that water to such an extent that it fails to comply with the requirements of national regulations.

For this purpose, reference shall be made to the relevant national regulations and standards, transposing EN standards when available, dealing with the influence of materials on water quality and to the requirements for external systems and components as given in EN 805.

NOTE A European Acceptance Scheme (EAS) is in course of development in relation to the Construction Products Directive and to the Drinking Water Directive ; its requirements will be introduced in this standard when completed.

4.2 Dimensional requirements

4.2.1 Wall thickness

4.2.1.1 General

The thickness shall be calculated either by the K class formula for pipes and fittings (see 4.2.1.2) or defined according to 4.2.1.3 for Class 40 pipes of DN 40 to DN 400.

For pipes, the standardized thickness classes are given in 8.1. Other thicknesses are possible for pipes by agreement between manufacturer and purchaser.

For fittings, the thickness e given in tables and on figures of 8.3 and 8.4 is the nominal thickness corresponding to the main part of the body. The actual thickness at any particular point may be increased to meet localized high stresses depending on the shape of the casting (e.g. at internal radius of bends, at the branch-body junction of tees,...).

Annex A gives the maximum values of PFA, PMA and PEA.

4.2.1.2 K classes for pipes and fittings

The nominal iron wall thickness of pipes and fittings is given as a function of the nominal size, DN, by the following formula, with a minimum of 6 mm for pipes and 7 mm for fittings:

$$e = K(0,5 + 0,001 DN) \quad (2)$$

where:

e is the nominal wall thickness, in millimetres;

DN is the nominal size;

K is a coefficient used for the determination of the thickness. It is selected from a series of whole numbers :.... 8, 9, 10, 11, 12.....

4.2.1.3 Class 40 for pipes

The nominal iron wall thickness of pipes DN 40 to DN 400 is given as a function of the nominal size, DN, in Table 15.

4.2.1.4 Tolerance

The tolerance on the nominal wall thickness of pipes and fittings shall be as given in Table 1. The measurement of the wall thickness shall be in accordance with 6.1.1.

EN 545:2006 (E)**Table 1**

Dimensions in millimetres

Type of casting	Nominal iron wall thickness e	Limit deviation on the nominal wall thickness ^a
Pipes centrifugally cast Class 40	$\leq 5,0$	- 1,3
	$> 5,0$	- (1,3 + 0,001 DN)
Pipes centrifugally cast K class	$\leq 6,0$	- 1,3
	$> 6,0$	- (1,3 + 0,001 DN)
Pipes not centrifugally cast and fittings	$\leq 7,0$	- 2,3
	$> 7,0$	- (2,3 + 0,001 DN)
^a The lower limit only is given, so as to ensure sufficient resistance to internal pressure.		

4.2.2 Diameter**4.2.2.1 External diameter**

8.1 specifies the values of the external diameter DE of the coated spigot ends of pipes and fittings and their maximum allowable tolerances, when measured using a circumferential tape in accordance with 6.1.2. These tolerances apply to the spigot ends of all thickness classes of pipes and fittings.

NOTE 1 Certain types of flexible joints operate within a different range of tolerance (see 4.1.3.3).

For $DN \leq 300$, the external diameter of the pipe barrel measured with a circumferential tape shall be such as to allow the assembly of the joint over at least two thirds of the pipe length from the spigot end when the pipe needs to be cut on site.

For $DN > 300$, the same applies to a percentage of the pipes, defined by agreement between manufacturer and purchaser. Such pipes shall be marked.

In addition, the ovality (see 3.26) of the spigot end of pipes and fittings shall:

- remain within the tolerance on DE (see Table 15) for DN 40 to DN 200;
- not exceed 1 % for DN 250 to DN 600 or 2 % for $DN > 600$.

NOTE 2 The manufacturer's guidance should be followed as to the necessity and means of ovality correction; certain types of flexible joints can accept the maximum ovality without a need for spigot re-rounding prior to jointing.

4.2.2.2 Internal diameter

The nominal values of the internal diameter of centrifugally cast pipes, expressed in millimetres, are equal to the numbers indicating their nominal size, DN, and the tolerances shall be as given in Table 2 which applies to lined pipes.

These tolerances apply to pipe thickness classes up to K10 and to cement mortar lining thicknesses as given in Table 8. Where greater iron and/or cement mortar lining thicknesses are agreed between manufacturer and purchaser, these tolerances do not apply.

NOTE Due to the manufacturing process of ductile iron pipes and their internal linings, internal diameters with the lower limit deviation will only appear locally along the pipe length.

Compliance shall be demonstrated according to 6.1.3 or by calculation from the measurements taken for pipe external diameter, iron wall thickness and lining thickness.

Table 2

DN	Limit deviation ^a mm
40 to 1 000	- 10
1 100 to 2 000	- 0,01 DN
^a The lower limit only is given.	

4.2.3 Length

4.2.3.1 Standardized lengths of socket and spigot pipes

Pipes shall be supplied to the standardized lengths given in Table 3.

Table 3

DN	Standardized lengths, L_u ^a m
40 and 50	3
60 to 600	5 or 5,5 or 6
700 and 800	5,5 or 6 or 7
900 to 1 400	6 or 7 or 8,15
1 500 to 2 000	8,15
^a See 3.24.	

The permissible deviations (see 3.25) on the standardized length L_u of pipes shall be as follows :

- for standardized length 8,15 m : ± 150 mm ;
- for all other standardized lengths : ± 100 mm.

Pipes shall be designed to a length taken in the range : standardized length plus or minus the permissible deviation; they shall be manufactured to this design length plus or minus the limit deviation given in Table 6.

The manufacturer shall show his design lengths in his catalogues.

The length shall be measured according to 6.1.4 and shall be within the limit deviations given in Table 6.

Of the total number of socket and spigot pipes to be supplied in each diameter, the percentage of shorter pipes shall not exceed 10 %, in which case the length reduction shall be :

- up to 0,15 m for the pipes in which samples have been cut for testing (see 4.3);
- up to 2 m by increments of 0,5 m for DN < 700;
- up to 3 m by increments of 0,1 m for DN ≥ 700 .

4.2.3.2 Standardized lengths of flanged pipes

Pipes shall be supplied to the standardized lengths given in Table 4.

EN 545:2006 (E)**Table 4**

Type of pipe	DN	Standardized lengths L^a m
With cast flanges	40 to 2 000	0,5 or 1 or 2 or 3
With screwed or welded flanges	40 to 600	2 or 3 or 4 or 5
	700 to 1 000	2 or 3 or 4 or 5 or 6
	1 100 to 2 000	4 or 5 or 6 or 7
^a See 3.24. Other lengths are available by agreement between manufacturer and purchaser.		

4.2.3.3 Standardized lengths of fittings

Fittings shall be supplied to the standardized lengths as given in 8.3 and 8.4.

NOTE Two series of dimensions are shown, the series A corresponding to ISO 2531 and the series B, generally limited up to DN 450.

The permissible deviations (see 3.25) on the standardized length of series A fittings shall be as given in Table 5. No deviation is permitted for the fittings of series B. Fittings shall be designed to a length taken in the range: standardized length plus or minus the permissible deviation; they shall be manufactured to this design length plus or minus the limit deviations given in Table 6.

Table 5

Type of fitting	DN	Deviation mm
Flanged sockets	40 to 1 200	± 25
Flanged spigots	1 400 to 2 000	± 35
Collars, tapers		
Tees	40 to 1 200	+ 50/- 25
	1 400 to 2 000	+ 75/- 35
Bends 90° (1/4)	40 to 2 000	± (15 + 0,03 DN)
Bends 45° (1/8)	40 to 2 000	± (10 + 0,025 DN)
Bends 22° 30' and 11° 15' (1/6 and 1/32)	40 to 1 200	± (10 + 0,02 DN)
	1 400 to 2 000	± (10 + 0,025 DN)

4.2.3.4 Tolerances on lengths

The limit deviations on lengths shall be as given in Table 6.

Table 6

Type of castings	Limit deviations mm
Socket and spigot pipes (full length or shortened)	- 30/+ 70
Fittings for socketed joints	± 20
Pipes and fittings for flanged joints	± 10 ^a
^a By agreement between manufacturer and purchaser, smaller limit deviations are possible, but not less than ± 3 mm for DN ≤ 600 and ± 4 mm for DN > 600.	

4.2.4 Straightness of pipes

Pipes shall be straight, with a maximum deviation of 0,125 % of their length.

The verification of this requirement is usually carried out by visual inspection, but in case of doubt or in dispute the deviation shall be measured in accordance with 6.2.

4.3 Material characteristics

4.3.1 Tensile properties

Pipes, fittings and accessories of ductile iron shall have the tensile properties given in Table 7.

The tensile strength shall be tested in accordance with 6.3.

Table 7

Type of casting	Minimum tensile strength, R_m MPa	Minimum elongation after fracture, A %	
	DN 40 to DN 2 000	DN 40 to DN 1 000	DN 1 100 to DN 2000
Pipes centrifugally cast	420	10	7
Pipes not centrifugally cast, fittings and accessories	420	5	5
<p>By agreement between manufacturer and purchaser, the 0,2 % proof stress ($R_{p0,2}$) may be measured. It shall be not less than :</p> <ul style="list-style-type: none"> - 270 MPa when $A \geq 12$ % for DN 40 to DN 1 000 or $A \geq 10$ % for DN > 1 000 ; - 300 MPa in other cases. <p>For centrifugally cast pipes of DN 40 to DN 1 000, the minimum elongation after fracture shall be 7 % for thickness classes over K12.</p>			

4.3.2 Hardness

The hardness of the various components shall be such that they can be cut, drilled, tapped and/or machined with normal tools. In case of dispute, the hardness shall be measured by the Brinell Hardness test in accordance with 6.4.

The Brinell hardness shall not exceed 230 HB for pipes and 250 HB for fittings and accessories. For components manufactured by welding, a higher Brinell hardness is allowed in the heat affected zone of the weld.

EN 545:2006 (E)**4.4 Coatings and linings for pipes****4.4.1 General**

Unless otherwise agreed between manufacturer and purchaser, all pipes shall be delivered with an external metallic zinc coating with finishing layer in accordance with 4.4.2, and an internal lining of cement mortar in accordance with 4.4.3.

The joint areas are generally coated as follows:

- external surface of spigot ends : same as external pipe coating;
- flanges and sockets (face and internal surface): bituminous paint or synthetic resin paint, alone or as a supplement to a primer or zinc coating.

Other coatings may also be supplied, depending on the external and internal conditions of use (see Annex D).

These external and internal coatings shall comply with the corresponding European Standards or, where no European Standards exists, they shall comply with International Standards or with National Standards, or with an agreed technical specification.

All finished internal coatings (linings) shall comply with 4.1.4.

NOTE 1 The field of use of these coatings and linings is given in Annexes D and E.

NOTE 2 Pipes with cast flanges can be coated as fittings (see 4.5).

NOTE 3 The maximum fluid temperature is limited to 35°C for some polymeric coatings. If such coatings are to be used at higher temperatures, additional performance testing should be carried out.

4.4.2 External coating of zinc with finishing layer**4.4.2.1 General**

The external coating of centrifugally cast ductile iron pipes shall comprise a layer of metallic zinc, covered by a finishing layer of a bituminous product or synthetic resin compatible with zinc. Both layers shall be works applied.

The zinc is normally applied on oxide-surfaced pipes after heat treatment; at the manufacturer's option, it may also be applied on blast-cleaned pipes. Prior to application of zinc, the pipe surface shall be dry and free from rust or non-adhering particles or foreign matter such as oil or grease.

4.4.2.2 Coatings characteristics

The metallic zinc coating shall cover the external surface of the pipe and provide a dense, continuous, uniform layer. It shall be free from such defects as bare patches or lack of adhesion. The uniformity of the coating shall be checked by visual inspection. When measured in accordance with 6.6, the mean mass of zinc per unit area shall be not less than 130 g/m². The purity of the zinc used shall be at least 99,99%.

The finishing layer shall uniformly cover the whole surface of the metallic zinc layer and be free from such defects as bare patches or lack of adhesion. The uniformity of the finishing layer shall be checked by visual inspection. When measured in accordance with 6.7, the mean thickness of the finishing layer shall be not less than 70 µm and the local minimum thickness not less than 50 µm.

4.4.2.3 Repairs

Damage to coatings where the area of total removal of zinc and finishing layer has a width exceeding 5 mm and areas left uncoated (e.g. under test token, see 6.6) shall be repaired.

Repairs shall be carried out by :

- metallic zinc spray complying with 4.4.2.2, or application of zinc-rich paint containing at least 90 % zinc by mass of dry film and with a mean mass of applied paint not less than 150 g/m²; and
- application of a finishing layer complying with 4.4.2.2.

4.4.3 Internal lining of cement mortar

4.4.3.1 General

Unless specified in the corresponding European Standard, the internal cement mortar lining of ductile iron pipes shall comply with the following requirements.

The cement mortar lining of ductile iron pipes shall constitute a dense, homogeneous layer covering the total internal surface of the pipe barrel.

It shall be works-applied by a centrifugal spinning process or a centrifugal spray head or a combination of these methods. Smoothing with a trowel is permitted.

Prior to application of the lining, the metal surface shall be free from loose material and oil or grease.

The cement mortar mix shall comprise cement, sand and water. If admixtures are used, they shall comply with 4.1.4, and they shall be declared. The ratio by mass of sand to cement shall not exceed 3,5. At the mixing stage, the ratio by mass of total water to cement depends on the manufacturing process and shall be determined such that the lining is in accordance with 4.4.3.2 and 4.4.3.3.

The cement shall be one of those listed in EN 197-1 or sulphate resisting cement. High alumina cement may be used for raw water or for specific applications as agreed between manufacturer and purchaser. The cured lining shall comply with 4.1.4. The sand shall have an appropriate grading and shall not contain organic impurities or fine clay particles which may affect the lining quality. The water used in the mortar mix shall be drinking water or water of comparable quality.

After application of the fresh lining, controlled curing shall be carried out so as to provide sufficient hydration to the cement.

The cured lining shall comply with 4.1.4, 4.4.3.2 and 4.4.3.3.

4.4.3.2 Strength of the lining

When measured in accordance with 7.1, the compressive strength of the cement mortar after 28 days of curing shall be not less than 50 MPa.

NOTE The compressive strength of the lining is directly related to other functional properties such as high density, good bond and low porosity.

4.4.3.3 Thickness and surface condition

The nominal thickness of the cement mortar lining and its tolerance shall be as given in Table 8. When measured in accordance with 6.8, the lining thickness shall be within the specified tolerance.

The surface of the cement mortar lining shall be uniform and smooth. Trowel marks, protrusion of sand grains and surface texture inherent to the method of manufacture are acceptable. But there shall be no recesses or local defects which reduce the thickness to below the minimum value given in Table 8.

Fine crazing and hairline cracks associated with cement rich surface may appear in dry linings. When shrinkage cracks inherent to cement-bound materials have developed in the dry linings, the crack width and the corresponding radial displacement shall not exceed the values given in Table 8.

EN 545:2006 (E)**Table 8**

Dimensions in millimetres

DN	Thickness		Maximum crack width and radial displacement
	Nominal value	Limit deviation ^a	
40 to 300	4	- 1,5	0,4
350 to 600	5	- 2,0	0,5
700 to 1 200	6	- 2,5	0,6
1 400 to 2 000	9	- 3,0	0,8
^a The lower limit only is given.			

NOTE 1 Cement mortar linings at pipe ends can have a chamfer of maximum length 20 mm.

NOTE 2 Storage of pipes and fittings in a hot, dry environment can cause metal expansion and mortar shrinkage which may result in the dry lining developing areas of disbondment and shrinkage cracks exceeding the width given in Table 8. When the lining is re-exposed to water, it will swell by absorption of moisture and the cracks will close to conform to Table 8 and will eventually heal by an autogenous process.

4.4.3.4 Repairs

Repairs to areas of damaged linings shall be effected by the use of either cement mortar (see 4.4.3.1) or a compatible polymer mortar ; application may be by hand.

Prior to the application of the repair mortar, the damaged area shall be cut back to the sound lining or to the metal surface and all loose material shall be removed. After completion of the repair, the lining shall be in accordance with 4.4.3.1, 4.4.3.2, 4.4.3.3, and 4.1.4.

4.5 Coatings for fittings and accessories**4.5.1 General**

Unless otherwise agreed between manufacturer and purchaser, all fittings, accessories and pipes not centrifugally cast shall be delivered externally and internally coated by a paint coating in conformity with 4.5.2; fittings may also receive an internal lining of cement mortar conforming with 4.4.3, machine or hand applied, as a supplement to or as a replacement of the above paint coating.

The following coatings may also be supplied, depending on the external and internal conditions of use:

a) External coatings :

- zinc rich-paint coating with finishing layer;
- polyethylene sleeving (as a supplement to the paint coating or to the zinc rich paint coating with finishing layer);
- thicker electro-deposited coating with a minimum thickness of 50 µm, applied on a blast-cleaned and phosphated surface;
- adhesive tape;
- epoxy coating.

b) Internal coatings (linings):

- thicker cement mortar lining;
- cement mortar lining with seal coat;
- thicker electro-deposited coating with a minimum thickness of 50 µm, applied on a blast-cleaned and phosphated surface;
- polyurethane coating;
- enamel coating;
- epoxy coating.

These external and internal coatings shall comply with the corresponding European Standards or, where no European Standard exists, they shall comply with International Standards or with National Standards, or with an agreed technical specification.

All finished internal coatings (linings) shall comply with 4.1.4.

NOTE The field of use of these coatings and linings is given in Annexes D and E.

4.5.2 Paint coating**4.5.2.1 General**

The coating material shall be of a bitumen or synthetic resin base. Appropriate additives (such as solvents, inorganic fillers, ...) to allow easy application and drying are permitted. Prior to application of the coating, the casting surface shall be dry, free from rust or non adhering particles or foreign matter such as oil or grease. The coating shall be works-applied.

4.5.2.2 Coating characteristics

The coating shall uniformly cover the whole surface of the casting and have a smooth regular appearance. Drying shall be sufficient to ensure that it will not stick to adjacent coated pieces.

When measured in accordance with 6.7, the mean thickness of the coating shall be not less than 70 µm and the local minimum thickness shall be not less than 50 µm. For electro-deposited synthetic resin based coatings, the coating thickness shall be not less than 35 µm.

4.6 Marking of pipes and fittings

All pipes and fittings shall be legibly and durably marked and shall bear at least the following information:

- the manufacturer's name or mark;
- the identification of the year of manufacture;
- the identification as ductile iron;
- the DN;
- the PN rating of flanges when applicable;
- the reference to this standard;
- the class designation of centrifugally cast pipes when other than K9.

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In addition, pipes of DN > 300 suitable for cutting shall be identified (unless all pipes of the same DN are suitable for cutting).

The first five markings given above shall be cast-on or cold stamped; the other markings can be applied by any method, e.g. painted on the casting or attached to the packaging.

4.7 Leak tightness

Pipes, fittings and joints shall be designed to be watertight at their allowable test pressure (PEA) :

- pipes and fittings shall be tested in accordance with 6.5 and shall exhibit no visible leakage, sweating or any other sign of failure;
- joints shall comply with the performance requirements of Clause 5.

5 Performance requirements for joints**5.1 General**

In order to ensure their fitness for purpose in the field of water supply, all the joints shall fulfil the performance requirements of Clause 5.

There shall be a performance test for at least one DN for each of the groupings given in Table 9. One DN is representative of a grouping when the performances are based on the same design parameters throughout the size range. If a grouping covers products of different designs and/or manufactured by different processes, the grouping shall be sub-divided.

Table 9

DN groupings	40 to 250	300 to 600	700 to 1 000	1 100 to 2 000
Preferred DN in each grouping	200	400	800	1 600

When flanges are involved, there shall be a performance test for at least one PN for each of the groupings given in Table 9. The PN to be tested is the highest PN existing for each flange design. One PN is representative of a grouping when the performances are based on the same design parameters throughout the size range. If a grouping covers products of different designs and/or manufactured by different processes, the grouping shall be sub-divided.

If for a manufacturer a grouping contains only one DN or PN, this DN or this PN may be considered as part of the adjacent grouping provided that it is of identical design and manufactured by the same process.

5.2 Flexible joints**5.2.1 General**

All joints shall be designed to be fully flexible; consequently, the allowable angular deflection declared by the manufacturer shall be not less than:

- 3° 30' for DN 40 to DN 300;
- 2° 30' for DN 350 to DN 600;
- 1° 30' for DN 700 to DN 2 000.

All joints shall be designed to provide sufficient axial movement; the allowable withdrawal shall be declared by the manufacturer.

NOTE This permits the installed pipeline to accommodate ground movements and/or thermal effects without incurring additional stresses.

5.2.2 Test conditions

All joint designs shall be performance tested under the most unfavourable applicable conditions of tolerance and joint movement as given below:

- a) joint of maximum annulus (see 5.2.3.1) aligned, withdrawn to the allowable value declared by the manufacturer, and subject to shear (see 5.2.3.3);
- b) joint of maximum annulus (see 5.2.3.1) deflected to the allowable value declared by the manufacturer (see 5.2.1).

The joints shall exhibit no visible leakage, and the pipes or the fittings being tested with the joints shall not exhibit any detrimental damage, when subjected to the tests given in Table 10.

Table 10

Test	Test requirements	Test conditions	Test method
1. Positive internal hydrostatic pressure	Test pressure: (1,5PFA + 5)bar Test duration: 2 h No visible leakage	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with 7.2
		Joint of maximum annulus, deflected	
2. Negative internal pressure	Test pressure: - 0,9 bar ^a Test duration: 2 h Maximum pressure change during test period: 0,09 bar	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with 7.3
		Joint of maximum annulus, deflected	
3. Positive external hydrostatic pressure	Test pressure: 2 bar Test duration: 2 h No visible leakage	Joint of maximum annulus, aligned, with shear load	In accordance with 7.4
4. Cyclic internal hydraulic pressure	24 000 cycles Test pressure: between PMA and (PMA – 5) bar No visible leakage	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with 7.5
^a 0,9 bar below atmospheric pressure (approximately 0,1 bar absolute pressure)			

Test 3 (positive external pressure) is not required for mechanical joints, provided they have been performance-tested according to tests 1 and 2.

Test 4 (cyclic internal hydraulic pressure) is not required for:

- the joints which have successfully performed in service 10 years prior to the date of the first publication of this standard;
- the joints which have already been successfully performance-tested before 2002 according to 7.5, but with the pressure cycled between PFA and 0,5 PFA (instead of PMA and PMA – 5).

EN 545:2006 (E)**5.2.3 Test parameters****5.2.3.1 Annulus**

All joints shall be performance tested at the extremes of manufacturing tolerance such that the annular gap between the sealing surfaces of the socket and of the spigot is equal to the maximum design value plus 0 %, minus 5 %. It is permissible to machine socket internal surfaces to achieve the required annulus for the performance-test even though the resultant diameter can be slightly outside the normal manufacturing tolerance.

5.2.3.2 Pipe thickness

All joints shall be performance tested with a spigot having an average iron wall thickness (over a distance of 2 DN, in millimetres, from the spigot end face) equal to the specified minimum value for the pipe for which the joint is designed plus 10 %, minus 0 %. It is permissible to machine the spigot end of the test pipe in the bore to achieve the required thickness.

5.2.3.3 Shear

All joints shall be performance tested with a resultant shear force across the joints of not less than 50 DN, in newtons, taking into account the weight of the pipe and of its contents and the geometry of the test assembly (see 7.2).

5.3 Restrained flexible joints

All restrained joints shall be designed to be at least semi-flexible; consequently, the allowable angular deflection declared by the manufacturer shall be not less than half the value shown in 5.2.1.

All restrained joint designs shall be performance-tested in accordance with 7.2 to 7.5 following the requirements of 5.2.2 and 5.2.3, except that:

- the withdrawal condition of 5.2.2 a) shall not apply;
- there shall be no external axial restraint in positive internal pressure tests so that the joint is subjected to the full end thrust.

During the positive internal pressure tests, the axial movement shall reach a stable value and cease.

When the restraining mechanism and the sealing component of a restrained joint are independent, such a joint does not need to be subjected to test 2 and test 3 of 5.2.2 if the unrestrained version of the joint has passed these tests.

5.4 Flanged joints

In order to demonstrate their strength and leak tightness in service conditions, flanged joints shall be subjected to a performance test. When tested in accordance with 7.6, they shall show no visible leakage under the combined effects of a hydrostatic internal pressure and of a bending moment given in Table 11, where:

- the pressure is $(1,5 P_N + 5)$ bar;
- the relevant bending moment is obtained by addition of the bending moments due to the weight of the components and of the water in the test assembly and to a possible external load calculated as a function of the length of the unsupported span of the testing arrangement (see 7.6).

NOTE The bending moments given in Table 11 are equal to those resulting from the weight of the pipes and of the water over an unsupported pipe length L between simple supports, with:

- $L = 8$ m for $DN \leq 250$;
- $L = 12$ m for $DN \geq 300$.

Table 11

DN	Bending moment kN·m	DN	Bending moment kN·m
40	0,7	500	63
50	0,9	600	87
60	1,3	700	116
65	1,4	800	146
80	1,8	900	181
100	2,3	1 000	222
125	2,9	1 100	265
150	4,0	1 200	313
200	6,0	1 400	423
250	8,6	1 500	475
300	26,0	1 600	548
350	33,8	1 800	625
400	42	2 000	770
450	51		

5.5 Pipes with screwed or welded flanges

In order to demonstrate the strength and the leak tightness of the flange attachment to the pipe in severe service conditions, pipes with screwed or welded flanges shall be subjected to a performance test. When tested in accordance with 7.7, they shall show no visible leakage under the combined effects of a hydrostatic internal pressure equal to 2 PN (in bars) and of an external load sufficient to cause the bending moments given in Table 12. The calculation of the external load to be applied shall take account of the bending moment due to the weight of the components and of the water in the test assembly.

NOTE 1 Flanged pipelines may be subjected in service to high bending moments caused by large unsupported spans and/or settlements of supports.

NOTE 2 The bending moments given in Table 12 are equal to four times those resulting from the weight of the pipes and of the water over an unsupported length L between simple supports, with:

- $L = 8$ m for $DN \leq 250$;

- $L = 12$ m for $DN \geq 300$.

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Table 12

DN	Bending moment kN·m	Minimum distance Y ^a (mm)		
		Class 40	K9	K10
40	2,9	128	132	132
50	3,7	131	135	135
60	5,2	134	139	139
65	5,6	135	140	140
80	7,2	139	145	145
100	9,3	144	150	150
125	11,6	149	156	156
150	16,0	155	161	163
200	24,0	165	171	176
250	34,2	175	183	188
300	104	186	194	201
350	135	200	205	212
400	168	214	216	224
450	205	-	227	235
500	251	-	238	247
600	348	-	259	270
700	463	-	281	292
800	584	-	302	315
900	724	-	323	337
1 000	886	-	343	359
1 100	1 060	-	364	381
1 200	1 250	-	385	403
1 400	1 690	-	427	447
1 500	1 900	-	447	469
1 600	2 190	-	468	491
1 800	2 500	-	509	535
2 000	3 080	-	551	579
^a See 7.7.				

6 Test methods

6.1 Pipe dimensions

6.1.1 Wall thickness

Pipe wall thickness compliance shall be demonstrated by the manufacturer. He may use a combination of various means, e.g. direct wall thickness measurement, mechanical or ultrasonic measurement.

The iron wall thickness shall be measured by suitable equipment having an error limit $\pm 0,1\text{mm}$.

6.1.2 External diameter

Socket and spigot pipes shall be measured at their spigot end by means of a circumferential tape or controlled by pass-fail gauges. In addition, they shall be visually inspected for compliance with the spigot allowable ovality and, in case of doubt, the maximum and minimum spigot axes shall be measured by suitable equipment or controlled by pass-fail gauges.

6.1.3 Internal diameter

The internal diameter of the lined pipes shall be measured by means of suitable equipment:

- a) either two measurements shall be taken at right angles, at a cross section 200 mm or more from the end face. The mean value of these two measurements may then be calculated;

or

- b) a system of pass / fail gauges shall be passed along the bore of the pipe.

6.1.4 Length

The length of socket and spigot pipes shall be measured by suitable equipment:

- on one pipe from the first batch of pipes cast from a new mould, for as-cast pipes;
- on the first pipe, for pipes which are systematically cut to a pre-set length.

6.2 Straightness of pipes

The pipe shall be rolled on two gantries or rotated around its axis on rollers, which in each case are separated by not less than two-thirds of the standardized pipe length.

The point of maximum deviation from the straight axis shall be determined and the deviation measured at that point.

6.3 Tensile testing

6.3.1 Samples

6.3.1.1 General

The thickness of the sample and the diameter of the test bar shall be as given in Table 13.

6.3.1.2 Centrifugally cast pipes

A sample shall be cut from the spigot end of the pipe. This sample may be cut parallel with or perpendicular to the pipe axis, but in case of dispute the parallel with axis sample shall be used.

6.3.1.3 Pipes not centrifugally cast, fittings and accessories

At the manufacturer's option, samples shall be either cast integrally with the castings or cast separately. In the latter case they shall be cast from the same metal as that used for the castings. If the castings are subjected to heat treatment, the samples shall be subjected to the same heat treatment cycle.

EN 545:2006 (E)**6.3.2 Preparation of test bar**

A test bar shall be machined from each sample to be representative of the metal at the mid thickness of the sample, with a cylindrical part having the diameter given in Table 13.

The test bar shall have a gauge length equal to at least five times the nominal test bar diameter. The ends of the test bar shall be such that they will fit the testing machine.

The surface roughness profile of the cylindrical part of the test bar shall be such that $R_z \leq 6,3$.

If the specified diameter of the test bar is greater than 60 % of the measured minimum thickness of the sample, it is allowed to machine a test bar with a smaller diameter.

Table 13

Type of casting	Nominal diameter of the test bar	Limit deviations on diameter	Tolerance on shape ^a
	mm	mm	mm
Centrifugally cast pipes, with a wall thickness (mm) of:			
— < 6	2,5	$\pm 0,06$	0,03
— 6 < 8	3,5		
— 8 < 12	5,0		
— ≥ 12	6,0		
Pipes not centrifugally cast, fittings and accessories:			
– integrally cast samples	5,0	$\pm 0,06$	0,03
– separately cast samples:			
– sample thickness 12,5 mm; for casting thickness < 12 mm;	6,0	$\pm 0,06$	0,03
– sample thickness 25 mm; for casting thickness 12 mm;	12,0	$\pm 0,09$	0,04
and over.	or 14,0	$\pm 0,09$	0,04
^a Maximum difference between the smallest and the largest measured diameter of the test bar.			

The tensile strength shall be calculated either from the nominal diameter of the test bar when it has been machined to fulfil all the tolerances given in Table 13, or, if it is not the case, from the actual diameter of the test bar measured before the test; the actual diameter shall be measured with an error limit $\leq 0,5$ % and shall be within ± 10 % of the nominal diameter.

6.3.3 Apparatus and test method

The tensile test shall be carried out in accordance to EN 10002-1.

6.3.4 Test results

Test results shall comply with Table 7. If they do not comply, the manufacturer shall:

- a) in the case where the metal does not achieve the required mechanical properties, investigate the reason and ensure that all castings in the batch are either re-heat treated or rejected. Castings which have been re-heat treated are then re-tested in accordance with 6.3;

NOTE The manufacturer may limit the amount of rejection by making tests until the rejected batch of castings is bracketed, in order of manufacture, by a successful test at each end of the interval in question.

- b) in the case of a defect in the test bar, carry out a further test. If it passes, the batch is accepted; if not, the manufacturer has the option to proceed as in a) above.

6.4 Brinell hardness

When Brinell hardness tests are carried out (see 4.3.2), they shall be performed either on the casting in dispute or on a sample cut from the casting. The surface to be tested shall be suitably prepared by slight local grinding and the test shall be carried out in accordance with EN ISO 6506-1 using a steel ball of 2,5 mm or 5 mm or 10 mm diameter.

6.5 Works leak tightness test for pipes and fittings

6.5.1 General

Pipes and fittings shall be tested in accordance with 6.5.2 and 6.5.3 respectively. The test shall be carried out on all pipes and fittings before the application of their external and internal coatings, except for the metallic zinc coating of pipes which may be applied before the test.

The test apparatus shall be suitable for applying the specified test pressures to the pipes and/or fittings. It shall be equipped with an industrial pressure gauge with an error limit $\pm 3\%$.

6.5.2 Centrifugally cast pipes

The internal hydrostatic pressure shall be raised steadily until it reaches the works hydrostatic test pressure given in Table 14, which is maintained for a sufficient time to allow visual inspection of the pipe barrel. The total duration of the pressure cycle shall be not less than 15 s, including 10 s at test pressure.

EN 545:2006 (E)**Table 14**

DN	Minimum works test pressure bar			
	Pipes centrifugally cast			Pipes not centrifugally cast and fittings ^a
	Class 40	K < 9	K ≥ 9	All thickness classes
40 to 300	40	0,5 (K+1) ²	50	25 ^b
350 to 600	40 ^c	0,5 K ²	40	16
700 to 1 000		0,5 (K-1) ²	32	10
1 100 to 2 000		0,5 (K-2) ²	25	10
^a The works hydrostatic test pressure is less for fittings than for pipes because the shape of the fittings makes it difficult to provide sufficient restraint to high internal pressure during the test. ^b 16 bar for pipes and fittings with PN 10 flanges. ^c The maximum DN for class 40 pipes is DN 400.				

6.5.3 Pipes not centrifugally cast and fittings

At the manufacturer's option, they shall be submitted to a hydrostatic pressure test, to an air test, or to a vacuum test of equivalent performance.

When the hydrostatic pressure test is carried out, it shall be in the same way as for centrifugally cast pipes (see 6.5.2), except for the test pressures which shall be as given in Table 14.

When the air test is carried out, it shall be with an internal pressure of at least 1 bar and a visual inspection time not less than 10 s; for leak detection, the castings shall be either uniformly coated on their external surface by a suitable foaming agent or submerged in water.

NOTE The test method for a vacuum test is not defined at the date of publication of this standard. It should be based on the detection of leakage of a known gas, by any means, when the casting is subjected to a vacuum, either internally or externally, the non-evacuated side being exposed to the known gas.

6.6 Zinc mass

A rectangular token of known weight per unit area shall be attached longitudinally along the axis of the pipe before passing it through the coating equipment. After zinc coating and trimming, the size of the token shall be 500 mm x 50 mm. It shall be weighed on a scale having an error limit ± 0,01 g.

The mean mass M of zinc per unit area shall be determined from the mass difference before and after coating.

$$M = C \left(\frac{M_2 - M_1}{A} \right) \quad (3)$$

where:

M is the mean mass of zinc in grammes per square metre;

M₁ and M₂ are the masses of the sample token, in grammes, before and after coating;

C is the predetermined correction factor, taking account of the nature of the token and of the difference in surface roughness between the token and the iron pipe;

A is the actual area of the trimmed token, in square metres.

NOTE The value of C, generally lying between 1 and 1,2, is given in the manufacturer's quality assurance plan.

The uniformity of the coating shall be checked by visual inspection of the token; in the event of a lack of uniformity, 50 mm x 50 mm pieces shall be cut from the token in the lighter mass zones and the mean mass of zinc determined on each piece by mass difference.

Alternatively the mass of zinc per unit area can be measured directly on the coated pipe by any method having proven correlation with the reference method described above, e.g. X-ray fluorescence or chemical analysis.

6.7 Thickness of paint coatings

The dry film thickness of paint coatings shall be measured by either of the three following methods:

- directly on the casting by means of suitable gauges, e.g. magnetic, or by using a 'wet film' thickness gauge where a correlation between wet film thickness and dry film thickness can be demonstrated;
- indirectly on a token which is attached to the casting before coating and is used after coating to measure the dry film thickness by mechanical means, e.g. micrometer, or by a weight method similar to 6.6;
- indirectly on a test plate made of steel or of ductile iron, which is coated by the same process as the castings to be controlled.

For each casting to be controlled, at least three measurements shall be taken (either on the casting or on the token or on a test plate). The mean thickness is the average of all the measurements taken and the local minimum thickness is the lowest value of all the measurements taken.

6.8 Thickness of cement mortar lining

During manufacture, the thickness shall be measured on the freshly applied lining by a spear having a diameter of 1,5 mm or less and controlled on the finished hardened lining by means of a suitable gauge, e.g. magnetic.

For pipes, the measurements shall be taken approximately 200 mm from the end face. The manufacturer's process control system shall specify the frequency of this test.

7 Performance test methods

7.1 Compressive strength of the cement mortar lining

The compressive strength shall be the arithmetic mean of six compressive strength tests performed on three prism samples after 28 days of curing.

The compressive strength shall be determined by a performance-test in accordance with EN 196-1, except that:

- the sand, the cement and the water used for the prism samples are identical with those used for the mortar before application of the lining;
- the sand/cement ratio used for the prism samples is equal to that used for the mortar before application of the lining;
- the water/cement ratio used for the prism samples is equal to that of the lining immediately after application to the pipe wall;
- the test samples are prepared using either an impact table (in accordance with EN 196-1) or a vibrating table (2 min at 63 Hz) when the water/cement ratio is below 0,35.

NOTE This takes into account the influence of the centrifugal spinning process which allows expelling the excess water.

EN 545:2006 (E)**7.2 Leak tightness of flexible joints to positive internal pressure**

The test shall be carried out on an assembled joint comprising two pipe sections, each at least 1 m long (see Figure 1).

The test apparatus shall be capable of providing suitable end and lateral restraints whether the joint is in the aligned position, or deflected, or subjected to a shear load. It shall be equipped with a pressure gauge with an error limit $\pm 3\%$.

The vertical force W shall be applied to the spigot end by means of a V shaped block with an angle of 120° , located at approximately $0,5\text{ DN}$ in millimetres or 200 mm from the socket face, whichever is the largest; the socket shall bear on a flat support. The vertical force W shall be such that the resultant shear force F across the joint is equal to the value specified in 5.2.3.3, taking into account the mass M of the pipe and its contents and the geometry of the test assembly:

$$W = \frac{F \cdot c - M (c - b)}{c - a} \quad (4)$$

where:

a , b and c are as shown in Figure 1.

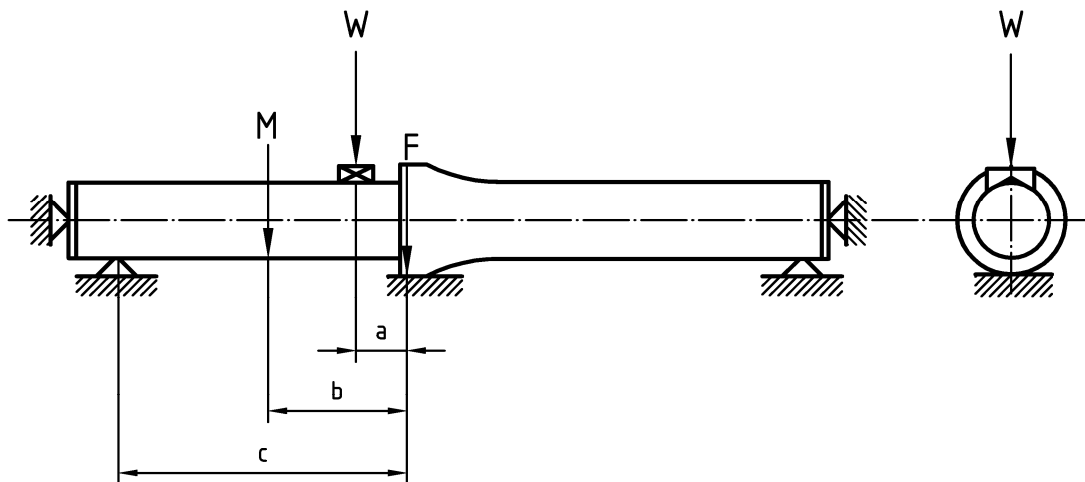


Figure 1

The test assembly shall be filled with water and suitably vented of air. The pressure shall be raised steadily until it reaches the test pressure given in 5.2.2; the rate of pressure increase shall not exceed 1 bar per s . The test pressure shall be kept constant within $\pm 0,5\text{ bar}$ for at least 2 h during which the joint shall be thoroughly inspected every 15 min .

All necessary safety precautions shall be taken for the duration of the pressure test.

For a restrained joint, the test assembly, the test apparatus and the test procedure shall be identical except that there shall be no end restraint, so that the axial thrust is taken by the restrained joint under test. In addition, possible axial movement of the spigot shall be measured every 15 min .

7.3 Leak tightness of flexible joints to negative internal pressure

The test assembly and test apparatus shall be as given in 7.2, with the pipe sections axially restrained to prevent them moving towards each other.

The test assembly shall be empty of water and shall be evacuated to a negative internal pressure of $0,9\text{ bar}$ (see 5.2.2) and then isolated from the vacuum pump. The test assembly shall be left under vacuum for at least 2 h

during which the pressure shall not have changed by more than 0,09 bar. The test shall begin at a temperature between 5 °C and 40 °C. The temperature of the test assembly shall not vary by more than 10 °C for the duration of the test.

For a restrained joint, the test assembly, the test apparatus and the test procedure are identical.

7.4 Leak tightness of flexible push-in joints to positive external pressure

The test assembly shall comprise two joints made with two pipe sockets welded together and one double-spigot piece (see Figure 2); it creates an annular chamber which allows testing one joint under internal pressure and one joint under external pressure.

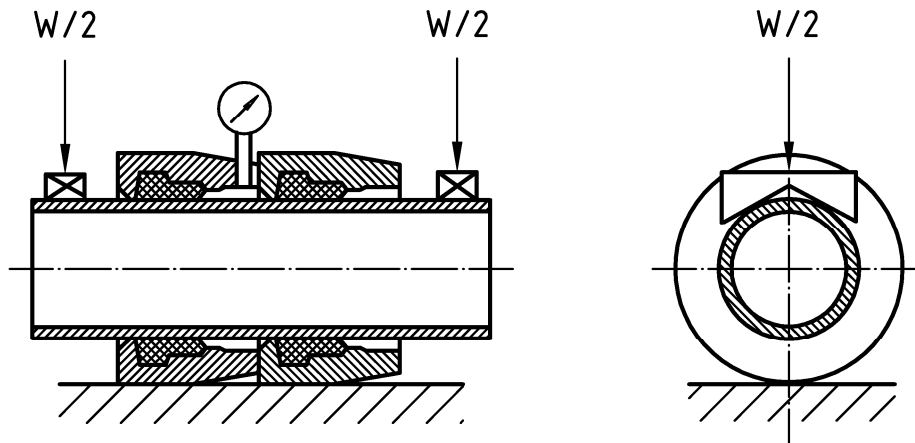


Figure 2

The test assembly shall be subjected to a vertical force W equal to the shear force F defined in 5.2.3.3; one half of this load shall be applied to the spigot end on each side of the test assembly, by means of a V shaped block with an angle of 120°, located at approximately 0,5 DN in millimetres or 200 mm from the ends of the sockets, whichever is the largest; the sockets shall bear on a flat support.

The test assembly shall be filled with water and suitably vented of air. The pressure shall be steadily increased until it reaches the test pressure of 2 bar. The latter shall be kept constant within $\pm 0,1$ bar for at least 2 h during which the internal side of the joint subjected to external pressure shall be thoroughly inspected every 15 min.

For a restrained joint, the test assembly, the test apparatus and the test procedure are identical.

7.5 Leak tightness of flexible joints to dynamic internal pressure

The test assembly and test apparatus shall be as given in 7.2. The test assembly shall be filled with water and suitably vented of air.

The pressure shall be steadily increased up to PMA, the allowable maximum operating pressure of the joint, then automatically monitored according to the following pressure cycle:

- a) steady pressure reduction to $(PMA - 5)$ bar;
- b) maintain $(PMA - 5)$ bar for at least 5 s;
- c) steady pressure increase to PMA;
- d) maintain PMA for at least 5 s.

The number of cycles shall be recorded and the test stopped automatically in the occurrence of a failure of the joint.

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For a restrained joint, the test assembly, the test apparatus and the test procedure are identical, except that there shall be no end restraint so that the axial thrust is taken by the restrained joint under test. In addition, any axial movement at the spigot shall be measured every 15 min.

All necessary safety precautions shall be taken for the duration of the pressure test.

7.6 Leak tightness and mechanical resistance of flanged joints

The test assembly shall comprise two relevant pipes or fittings with identical flanges, assembled together by means of the relevant gasket and bolts defined by the manufacturer. Both ends of the test assembly shall be equipped with blank flanges. The bolts shall be tightened to the torque given by the manufacturer for the maximum PN of the DN under test. The bolt material grade, when not defined, shall be grade 4.6 of EN ISO 4016.

The test assembly shall be placed on two simple supports (see Figure 3) such that the assembled flanged joint is positioned at mid span. The minimum length of unsupported span shall be either 6 DN in millimetres or 4 000 mm, whichever is the smallest. This length can be obtained by a combination of pipes or fittings, but only the tested joint at mid span shall be considered.

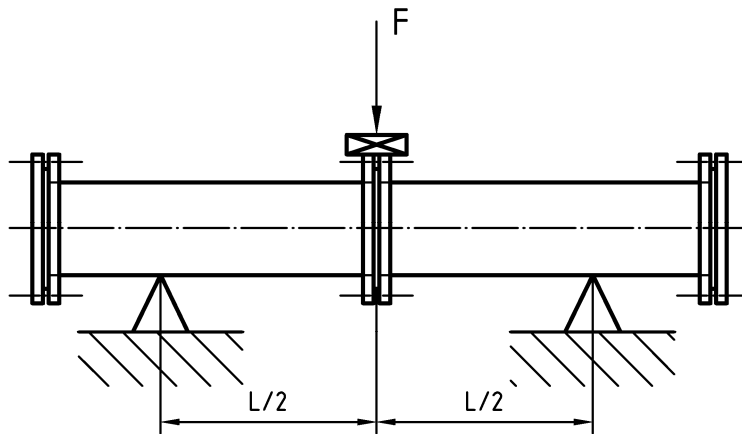


Figure 3

The test assembly shall be filled with water and suitably vented of air. The pressure shall be raised steadily until it reaches the test pressure given in 5.4. The external load F shall be applied to the assembled flanged joint by means of a flat plate, in a direction perpendicular to the axis of the test assembly, so as to cause the bending moment given in Table 11.

The internal pressure and the external load shall be kept constant for 2 h during which the flanged joint shall be thoroughly inspected.

All necessary safety precautions shall be taken for the duration of the pressure test.

7.7 Leak tightness and mechanical resistance of screwed and welded flanges

The test assembly shall comprise two flanged pipes of approximately equal length, assembled together by means of a flanged joint; both ends of the test assembly shall be equipped with blank flanges.

The wall thickness of pipe used in the performance test shall be the specified minimum thickness e_{\min} (in millimetres) of its class plus 10 % minus 0 % over a distance Y (in millimetres) from the jointing face of each flange at the joint to be tested:

$$Y = 100 + 2,3 (DN \cdot e_{\min})^{0,5} \quad (5)$$

NOTE 1 See Table 12 for values of Y .

The test assembly shall be placed on two simple supports such that the assembled flanged joint is positioned at mid span. The minimum length of unsupported span shall be either 6 DN in millimetres or 4 000 mm whichever is the smallest.

The test assembly shall be filled with water and suitably vented of air. The pressure shall be raised steadily until it reaches the test pressure given in 5.5. The external load shall be applied to the assembled flanged joint by means of a flat plate, in a direction perpendicular to the axis of the test assembly, so as to cause the bending moment given in Table 12.

The internal pressure and the external load are kept constant for 15 min during which the flanged joint shall be thoroughly inspected.

All necessary safety precautions shall be taken for the duration of the pressure test.

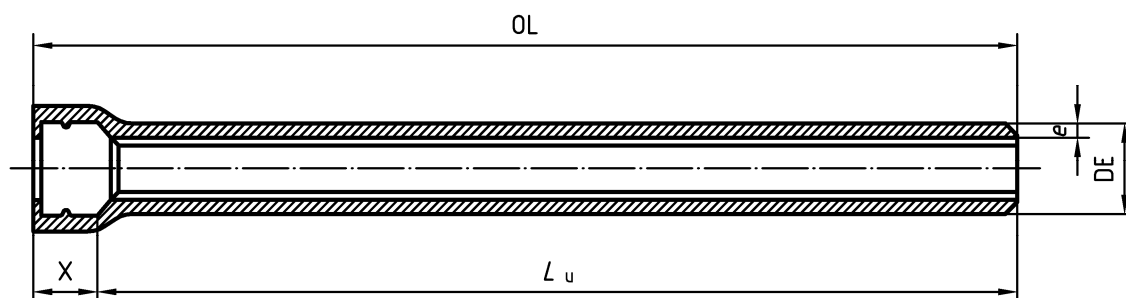
NOTE 2 The elevated pressures and bending moments applied in the test result in a loading significantly greater than that acting normally in service. Consequently, the test can require the use of gaskets and bolts of higher performance than those normally supplied and the application of bolt torques in excess of those normally applied during site installation.

8 Tables of dimensions

8.1 Socket and spigot pipes

The dimensions of socket and spigot pipes shall be as given in Table 15. The values of L_u are given in Table 3. For external and internal coatings, see 4.4.

The values of DE and their tolerances also apply to the spigot ends of fittings (see 4.2.2.1).



Key

OL overall length, in metres;
 X maximum insertion depth, in metres;
 $L_u = OL - X$ effective length, in metres.

Figure 4

EN 545:2006 (E)**Table 15**

DN	External diameter DE mm		Wall thickness e mm					
			Class 40		K9		K10	
	Nominal	Limit deviations	Nominal ^a	Limit deviation ^b	Nominal	Limit deviation ^b	Nominal	Limit deviation ^b
40	56	+ 1/-1,2	4,8	- 1,3	6,0	- 1,3	6,0	- 1,3
50	66	+ 1/-1,2	4,8	- 1,3	6,0	- 1,3	6,0	- 1,3
60	77	+ 1/-1,2	4,8	- 1,3	6,0	- 1,3	6,0	- 1,3
65	82	+ 1/-1,2	4,8	- 1,3	6,0	- 1,3	6,0	- 1,3
80	98	+ 1/-2,7	4,8	- 1,3	6,0	- 1,3	6,0	- 1,3
100	118	+ 1/-2,8	4,8	- 1,3	6,0	- 1,3	6,0	- 1,3
125	144	+ 1/-2,8	4,8	- 1,3	6,0	- 1,3	6,2	- 1,4
150	170	+ 1/-2,9	5,0	- 1,3	6,0	- 1,3	6,5	- 1,5
200	222	+ 1/-3,0	5,4	- 1,5	6,3	- 1,5	7,0	- 1,5
250	274	+ 1/-3,1	5,8	- 1,6	6,8	- 1,6	7,5	- 1,6
300	326	+ 1/-3,3	6,2	- 1,6	7,2	- 1,6	8,0	- 1,6
350	378	+ 1/-3,4	7,0	- 1,7	7,7	- 1,7	8,5	- 1,7
400	429	+ 1/-3,5	7,8	- 1,7	8,1	- 1,7	9,0	- 1,7
450	480	+ 1/-3,6			8,6	- 1,8	9,5	- 1,8
500	532	+ 1/-3,8			9,0	- 1,8	10,0	- 1,8
600	635	+ 1/-4,0			9,9	- 1,9	11,0	- 1,9
700	738	+ 1/-4,3			10,8	- 2,0	12,0	- 2,0
800	842	+ 1/-4,5			11,7	- 2,1	13,0	- 2,1
900	945	+ 1/-4,8			12,6	- 2,2	14,0	- 2,2
1 000	1 048	+ 1/-5,0			13,5	- 2,3	15,0	- 2,3
1 100	1 152	+ 1/-6,0			14,4	- 2,4	16,0	- 2,4
1 200	1 255	+ 1/-5,8			15,3	- 2,5	17,0	- 2,5
1 400	1 462	+ 1/-6,6			17,1	- 2,7	19,0	- 2,7
1 500	1 565	+ 1/-7,0			18,0	- 2,8	20,0	- 2,8
1 600	1 668	+ 1/-7,4			18,9	- 2,9	21,0	- 2,9
1 800	1 875	+ 1/-8,2			20,7	- 3,1	23,0	- 3,1
2 000	2 082	+ 1/-9,0			22,5	- 3,3	25,0	- 3,3

^a The nominal thickness of the Class 40 pipes is such that their PFA, calculated according to Annex A, is not less than 40 bar, with a minimum of 4,8 mm. In addition, in order to have consistency with the thickness series of K9 pipes, the nominal thickness of DN 150, DN 200, and DN 250 has been slightly increased above the calculated thickness corresponding to the PFA of 40 bar.

^b The lower limit only is given.

8.2 Flanged pipes

8.2.1 General

Standardized thickness classes, DN and PN of flanged pipes are specified in the following three sub-clauses. The values of L are given in Table 4. For coatings and linings, see 4.4.

8.2.2 Centrifugally cast pipes with welded flanges

- DN 40 to DN 450: K9 or Class 40 for PN 10, PN 16 and PN 25; K9 for PN 40
- DN 500 and DN 600: K9 for PN 10, PN 16 and PN 25; K10 for PN 40
- DN 700 to DN 1 600: K9 for PN 10, PN 16 and PN 25
- DN 1 800 and DN 2 000: K9 for PN 10 and PN 16

8.2.3 Centrifugally cast pipes with screwed flanges

- DN 40 to DN 450: K9 or K10 for PN 10, PN 16, PN 25 and PN 40
- DN 500 and DN 600: K9 or K10 for PN 10, PN 16 and PN 25; K10 for PN 40
- DN 700 to DN 1 200: K10 for PN 10, PN 16 and PN 25
- DN 1 400 to DN 2 000: K10 for PN 10 and PN 16

8.2.4 Pipes with integrally cast flanges

- DN 40 to DN 600: K12 for PN 10, PN 16, PN 25 and PN 40
- DN 700 to DN 1 600: K12 for PN 10, PN 16 and PN 25
- DN 1 800 and DN 2 000: K12 for PN 10 and PN 16

8.3 Fittings for socketed joints

8.3.1 General

In the following tables, all the dimensions are nominal values and are given in millimetres. The values of L_u and l_u have been rounded off to the nearest multiple of five.

For coating and linings, see 4.5.

8.3.2 Flanged sockets

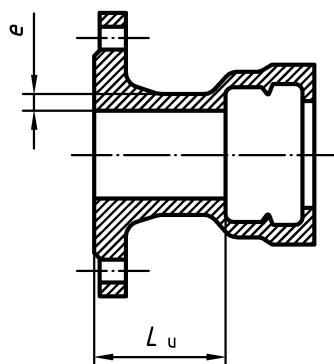


Figure 5a

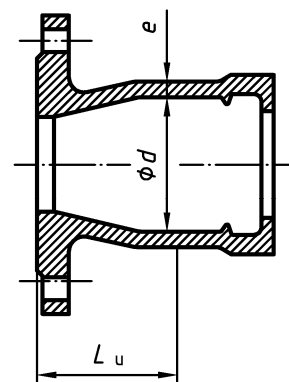


Figure 5b

Figure 5

EN 545:2006 (E)**Table 16**

DN	e	L_u series A	L_u series B	d
40	7,0	125	75	67
50	7,0	125	85	78
60	7,0	125	100	88
65	7,0	125	105	93
80	7,0	130	105	109
100	7,2	130	110	130
125	7,5	135	115	156
150	7,8	135	120	183
200	8,4	140	120	235
250	9,0	145	125	288
300	9,6	150	130	340
350	10,2	155	135	393
400	10,8	160	140	445
450	11,4	165	145	498
500	12,0	170	-	550
600	13,2	180	-	655
700	14,4	190	-	760
800	15,6	200	-	865
900	16,8	210	-	970
1 000	18,0	220	-	1 075
1 100	19,2	230	-	1 180
1 200	20,4	240	-	1 285
1 400	22,8	310	-	1 477
1 500	24,0	330	-	1 580
1 600	25,2	330	-	1 683
1 800	27,6	350	-	1 889
2 000	30,0	370	-	2 095

8.3.3 Flanged spigots

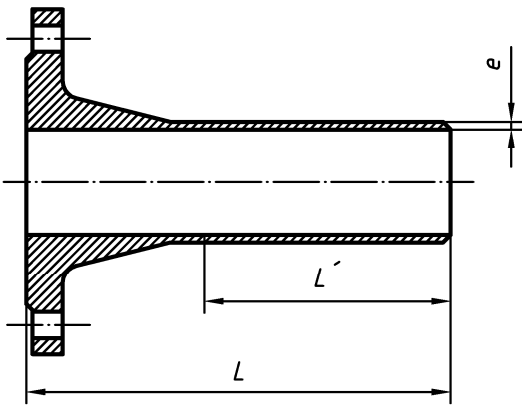


Figure 6

8.3.4 Collars

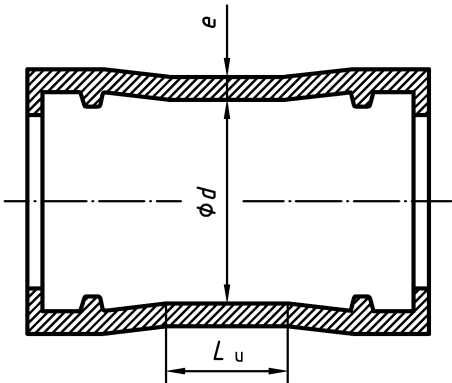


Figure 7

EN 545:2006 (E)**Table 17**

DN	e	Flanged spigots			Collars		
		L series A	L series B	L'	L _u series A	L _u series B	d
40	7,0	335	335	200	155	155	67
50	7,0	340	340	200	155	155	78
60	7,0	345	345	200	155	155	88
65	7,0	345	345	200	155	155	93
80	7,0	350	350	215	160	160	109
100	7,2	360	360	215	160	160	130
125	7,5	370	370	220	165	165	156
150	7,8	380	380	225	165	165	183
200	8,4	400	400	230	170	170	235
250	9,0	420	420	240	175	175	288
300	9,6	440	440	250	180	180	340
350	10,2	460	460	260	185	185	393
400	10,8	480	480	270	190	190	445
450	11,4	500	500	280	195	195	498
500	12,0	520	-	290	200	-	550
600	13,2	560	-	310	210	-	655
700	14,4	600	-	330	220	-	760
800	15,6	600	-	330	230	-	865
900	16,8	600	-	330	240	-	970
1 000	18,0	600	-	330	250	-	1 075
1 100	19,2	600	-	330	260	-	1 180
1 200	20,4	600	-	330	270	-	1 285
1 400	22,8	710	-	390	340	-	1 477
1 500	24,0	750	-	410	350	-	1 580
1 600	25,2	780	-	430	360	-	1 683
1 800	27,6	850	-	470	380	-	1 889
2 000	30,0	920	-	500	400	-	2 095
NOTE The length L' is the length to which the value of DE and its limit deviations, as given in Table 15, apply.							

8.3.5 Double socket 90° (1/4) bends

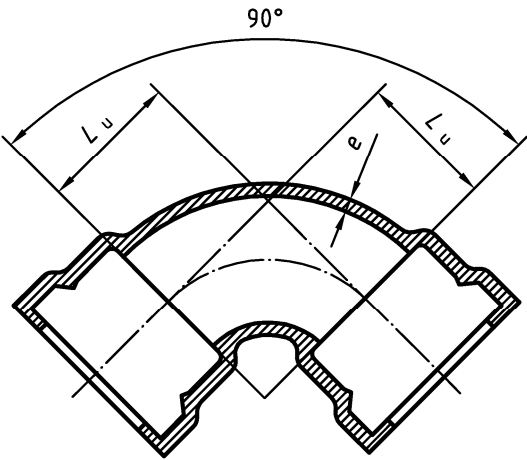


Figure 8

8.3.6 Double socket 45° (1/8) bends

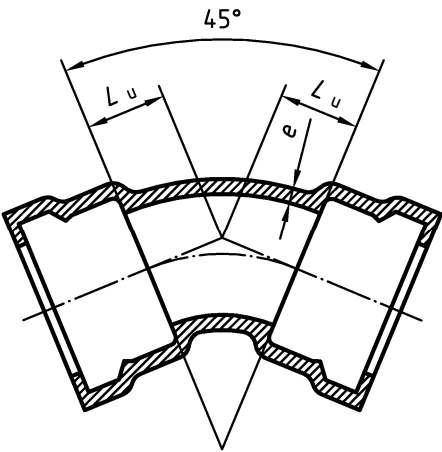


Figure 9

EN 545:2006 (E)**Table 18**

DN	e	90° (1/4) bends		45° (1/8) bends	
		<i>L_u</i> series A	<i>L_u</i> series B	<i>L_u</i> series A	<i>L_u</i> series B
40	7,0	60	85	40	85
50	7,0	70	85	40	85
60	7,0	80	90	45	90
65	7,0	85	90	50	90
80	7,0	100	85	55	50
100	7,2	120	100	65	60
125	7,5	145	115	75	65
150	7,8	170	130	85	70
200	8,4	220	160	110	80
250	9,0	270	240	130	135
300	9,6	320	280	150	155
350	10,2	-	-	175	170
400	10,8	-	-	195	185
450	11,4	-	-	220	200
500	12,0	-	-	240	-
600	13,2	-	-	285	-
700	14,4	-	-	330	-
800	15,6	-	-	370	-
900	16,8	-	-	415	-
1 000	18,0	-	-	460	-
1 100	19,2	-	-	505	-
1 200	20,4	-	-	550	-
1 400	22,8	-	-	515	-
1 500	24,0	-	-	540	-
1 600	25,2	-	-	565	-
1 800	27,6	-	-	610	-
2 000	30,0	-	-	660	-

8.3.7 Double socket 22° 30' (1/16) bends

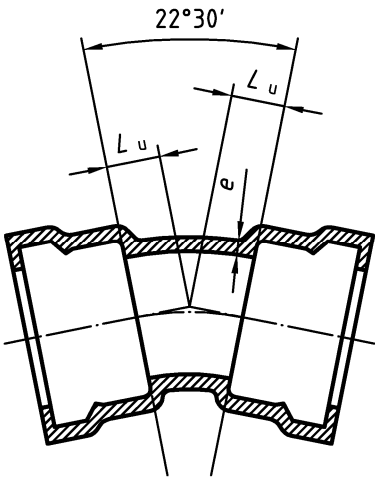


Figure 10

8.3.8 Double socket 11° 15' (1/32) bends

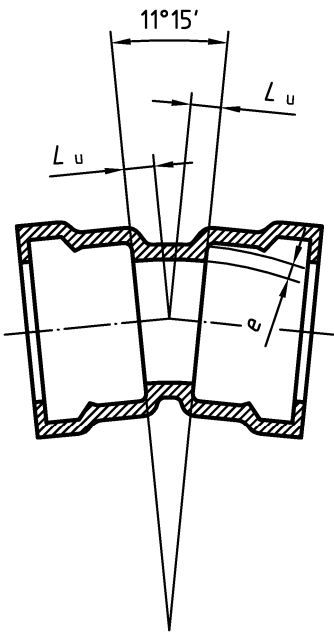


Figure 11

EN 545:2006 (E)

Table 19

DN	e	22°30' (1/16) bends		11°15' (1/32) bends	
		<i>L_u</i> series A	<i>L_u</i> series B	<i>L_u</i> series A	<i>L_u</i> series B
40	7,0	30	30	25	25
50	7,0	30	30	25	25
60	7,0	35	35	25	25
65	7,0	35	35	25	25
80	7,0	40	40	30	30
100	7,2	40	50	30	30
125	7,5	50	55	35	35
150	7,8	55	60	35	40
200	8,4	65	70	40	45
250	9,0	75	80	50	55
300	9,6	85	90	55	55
350	10,2	95	100	60	60
400	10,8	110	110	65	65
450	11,4	120	120	70	70
500	12,0	130	-	75	-
600	13,2	150	-	85	-
700	14,4	175	-	95	-
800	15,6	195	-	110	-
900	16,8	220	-	120	-
1 000	18,0	240	-	130	-
1 100	19,2	260	-	140	-
1 200	20,4	285	-	150	-
1 400	22,8	260	-	130	-
1 500	24,0	270	-	140	-
1 600	25,2	280	-	140	-
1 800	27,6	305	-	155	-
2 000	30,0	330	-	165	-

8.3.9 All socket tees

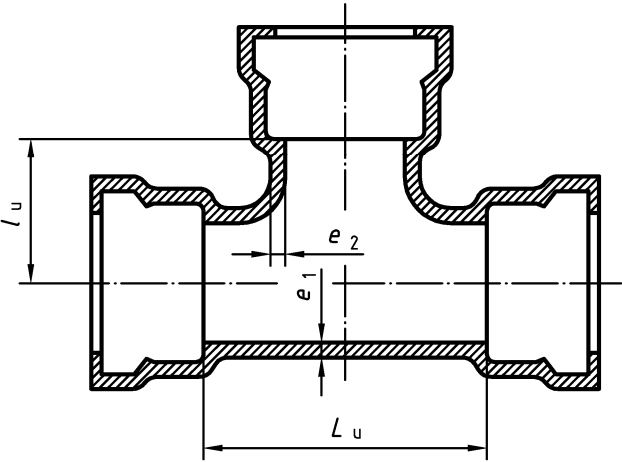


Figure 12

EN 545:2006 (E)**Table 20**

DN × dn	Body			Branch		
	e ₁	L _u series A	L _u series B	e ₂	I _u series A	I _u series B
40 × 40	7,0	120	155	7,0	60	75
50 × 50	7,0	130	155	7,0	65	75
60 × 60	7,0	145	155	7,0	70	80
65 × 65	7,0	150	155	7,0	75	80
80 × 40	7,0	120	155	7,0	80	80
80 × 80	7,0	170	175	7,0	85	85
100 × 40	7,2	120	155	7,0	90	90
100 × 60	7,2	145	155	7,0	90	90
100 × 80	7,2	170	165	7,0	95	90
100 × 100	7,2	190	195	7,2	95	100
125 × 40	7,5	125	155	7,0	100	105
125 × 80	7,5	170	175	7,0	105	105
125 × 100	7,5	195	195	7,2	110	115
125 × 125	7,5	225	225	7,5	110	115
150 × 40	7,8	125	160	7,0	115	115
150 × 80	7,8	170	180	7,0	120	120
150 × 100	7,8	195	200	7,2	120	125
150 × 150	7,8	255	260	7,8	125	130
200 × 40	8,4	130	165	7,0	140	140
200 × 80	8,4	175	180	7,0	145	145
200 × 100	8,4	200	200	7,2	145	150
200 × 150	8,4	255	260	7,8	150	155
200 × 200	8,4	315	320	8,4	155	160
250 × 80	9,0	180	185	7,0	170	185
250 × 100	9,0	200	205	7,2	170	190
250 × 150	9,0	260	265	7,8	175	190
250 × 200	9,0	315	320	8,4	180	190
250 × 250	9,0	375	380	9,0	190	190
300 × 100	9,6	205	210	7,2	195	220
300 × 150	9,6	260	265	7,8	200	220
300 × 200	9,6	320	325	8,4	205	220
300 × 250	9,6	375	380	9,0	210	220
300 × 300	9,6	435	440	9,6	220	220

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn.

8.3.10 Double-socket tees with flanged branch, DN 40 to DN 250

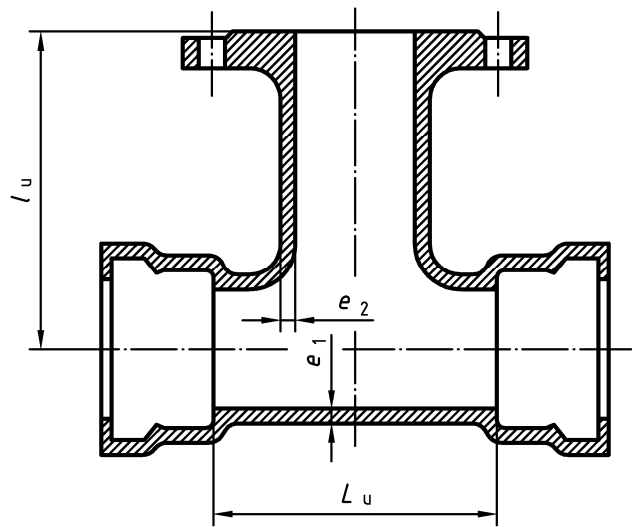


Figure 13

EN 545:2006 (E)**Table 21**

DN × dn	Body			Branch		
	e ₁	L _u series A	L _u series B	e ₂	I series A	I series B
40 × 40	7,0	120	155	7,0	130	130
50 × 50	7,0	130	155	7,0	140	140
60 × 40	7,0	-	155	7,0	-	130
60 × 60	7,0	145	155	7,0	150	150
65 × 40	7,0	-	155	7,0	-	130
65 × 65	7,0	150	155	7,0	150	155
80 × 40	7,0	-	155	7,0	-	135
80 × 60	7,0	-	155	7,0	-	155
80 × 80	7,0	170	175	7,0	165	165
100 × 40	7,2	-	155	7,0	-	145
100 × 60	7,2	-	155	7,0	-	165
100 × 80	7,2	170	165	7,0	175	170
100 × 100	7,2	190	195	7,2	180	180
125 × 40	7,5	-	155	7,0	-	160
125 × 60	7,5	-	155	7,0	-	180
125 × 80	7,5	170	175	7,0	190	185
125 × 100	7,5	195	195	7,2	195	195
125 × 125	7,5	225	225	7,5	200	200
150 × 40	7,8	-	160	7,0	-	170
150 × 60	7,8	-	160	7,0	-	190
150 × 80	7,8	170	180	7,0	205	200
150 × 100	7,8	195	200	7,2	210	205
150 × 125	7,8	-	230	7,5	-	215
150 × 150	7,8	255	260	7,8	220	220
200 × 40	8,4	-	165	7,0	-	195
200 × 60	8,4	-	165	7,0	-	215
200 × 80	8,4	175	180	7,0	235	225
200 × 100	8,4	200	200	7,2	240	230
200 × 125	8,4	-	235	7,5	-	240
200 × 150	8,4	255	260	7,8	250	245
200 × 200	8,4	315	320	8,4	260	260
250 × 60	9,0	-	165	7,0	-	260
250 × 80	9,0	180	180	7,0	265	265
250 × 100	9,0	200	205	7,2	270	270
250 × 150	9,0	260	265	7,8	280	280
250 × 200	9,0	315	320	8,4	290	290
250 × 250	9,0	375	380	9,0	300	300

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn.

8.3.11 Double-socket tees with flanged branch, DN 300 to DN 700

Table 22

DN × dn	Body			Branch		
	e ₁	L _u series A	L _u series B	e ₂	I series A	I series B
300 × 60	9,6	-	165	7,0	-	290
300 × 80	9,6	180	185	7,0	295	295
300 × 100	9,6	205	210	7,2	300	300
300 × 150	9,6	260	265	7,8	310	310
300 × 200	9,6	320	325	8,4	320	320
300 × 250	9,6	-	380	9,0	-	330
300 × 300	9,6	435	440	9,6	340	340
350 × 60	10,2	-	170	7,0	-	320
350 × 80	10,2	-	185	7,0	-	325
350 × 100	10,2	205	210	7,2	330	330
350 × 150	10,2	-	270	7,8	-	340
350 × 200	10,2	325	325	8,4	350	350
350 × 250	10,2	-	385	9,0	-	360
350 × 350	10,2	495	500	10,2	380	380
400 × 80	10,8	185	190	7,0	355	355
400 × 100	10,8	210	210	7,2	360	360
400 × 150	10,8	270	270	7,8	370	370
400 × 200	10,8	325	330	8,4	380	380
400 × 250	10,8	-	385	9,0	-	390
400 × 300	10,8	440	445	9,6	400	400
400 × 400	10,8	560	560	10,8	420	420
450 × 100	11,4	-	215	7,2	-	390
450 × 150	11,4	-	270	7,8	-	400
450 × 200	11,4	-	330	8,4	-	410
450 × 250	11,4	-	390	9,0	-	420
450 × 300	11,4	-	445	9,6	-	430
450 × 400	11,4	-	560	10,8	-	450
450 × 450	11,4	-	620	11,4	-	460
500 × 100	12,0	215	-	7,2	420	-
500 × 200	12,0	330	-	8,4	440	-
500 × 400	12,0	565	-	10,8	480	-
500 × 500	12,0	680	-	12,0	500	-
600 × 200	13,2	340	-	8,4	500	-
600 × 400	13,2	570	-	10,8	540	-
600 × 600	13,2	800	-	13,2	580	-
700 × 200	14,4	345	-	8,4	525	-
700 × 400	14,4	575	-	10,8	555	-
700 × 700	14,4	925	-	14,4	600	-

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn.

EN 545:2006 (E)**8.3.12 Double-socket tees with flanged branch DN 800 to DN 2 000****Table 23**

DN × dn	Body		Branch	
	e ₁	L _u series A	e ₂	I series A
800 × 200	15,6	350	8,4	585
800 × 400	15,6	580	10,8	615
800 × 600	15,6	1045	13,2	645
800 × 800	15,6	1045	15,8	675
900 × 200	16,8	355	8,4	645
900 × 400	16,8	590	10,8	675
900 × 600	16,8	1170	13,2	705
900 × 900	16,8	1170	16,8	750
1 000 × 200	18,0	360	8,4	705
1 000 × 400	18,0	595	10,8	735
1 000 × 600	18,0	1290	13,2	765
1 000 × 1 000	18,0	1290	18,0	825
1 100 × 400	19,2	600	10,8	795
1 100 × 600	19,2	830	13,2	825
1 200 × 600	20,4	840	13,2	885
1 200 × 800	20,4	1070	15,6	915
1 200 × 1 000	20,4	1300	18,0	945
1 400 × 600	22,8	1030	13,2	980
1 400 × 800	22,8	1260	15,6	1 010
1 400 × 1 000	22,8	1495	18,0	1 040
1 500 × 600	24,0	1035	13,2	1 035
1 500 × 1 000	24,0	1500	18,0	1 595
1 600 × 600	25,2	1040	13,2	1 090
1 600 × 800	25,2	1275	15,6	1 120
1 600 × 1 000	25,2	1505	18,0	1 150
1 600 × 1 200	25,2	1740	20,4	1 180
1 800 × 600	27,6	1055	13,2	1 200
1 800 × 800	27,6	1285	15,6	1 230
1 800 × 1 000	27,6	1520	18,0	1 260
1 800 × 1 200	27,6	1750	20,4	1 290
2 000 × 600	30,0	1065	13,2	1 310
2 000 × 1 000	30,0	1530	18,0	1 370
2 000 × 1 400	30,0	1995	22,8	1 430

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn.

8.3.13 Double-socket tapers

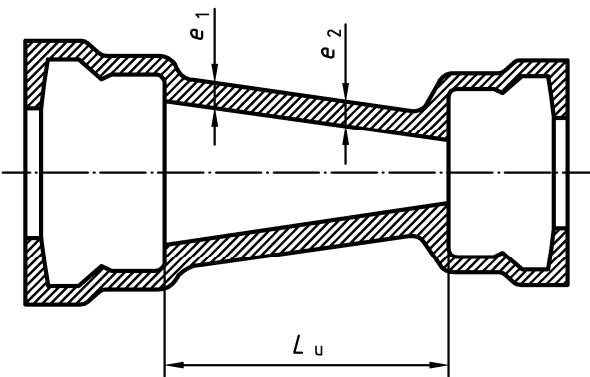


Figure 14

EN 545:2006 (E)**Table 24**

DN × dn	e₁	e₂	L_u series A	L_u series B
50 × 40	7,0	7,0	70	75
60 × 50	7,0	7,0	70	75
65 × 50	7,0	7,0	80	75
80 × 40	7,0	7,0	-	80
80 × 60	7,0	7,0	90	80
80 × 65	7,0	7,0	80	80
100 × 60	7,2	7,0	-	120
100 × 80	7,2	7,0	90	85
125 × 60	7,5	7,0	-	190
125 × 80	7,5	7,0	140	135
125 × 100	7,5	7,2	100	120
150 × 80	7,8	7,0	190	190
150 × 100	7,8	7,2	150	150
150 × 125	7,8	7,5	100	115
200 × 100	8,4	7,2	250	250
200 × 125	8,4	7,5	200	230
200 × 150	8,4	7,8	150	145
250 × 125	9,0	7,5	300	335
250 × 150	9,0	7,8	250	250
250 × 200	9,0	8,4	150	150
300 × 150	9,6	7,8	350	370
300 × 200	9,6	8,4	250	250
300 × 250	9,6	9,0	150	150
350 × 200	10,2	8,4	360	370
350 × 250	10,2	9,0	260	260
350 × 300	10,2	9,6	160	160
400 × 250	10,8	9,0	360	380
400 × 300	10,8	9,6	260	260
400 × 350	10,8	10,2	160	155
450 × 350	11,4	10,2	260	270
450 × 400	11,4	10,8	160	160
500 × 350	12,0	10,2	360	-
500 × 400	12,0	10,8	260	-
<i>(to be continued)</i>				

Table 24 (concluded)

DN × dn	e ₁	e ₂	L _u series A	L _u series B
600 × 400	13,2	10,8	460	-
600 × 500	13,2	12,0	260	-
700 × 500	14,4	12,0	480	-
700 × 600	14,4	13,2	280	-
800 × 600	15,6	13,2	480	-
800 × 700	15,6	14,4	280	-
900 × 700	16,8	14,4	480	-
900 × 800	16,8	15,6	280	-
1 000 × 800	18,0	15,6	480	-
1 000 × 900	18,0	16,8	280	-
1 100 × 1 000	19,2	18,0	280	-
1 200 × 1 000	20,4	18,0	480	-
1 400 × 1 200	22,8	20,4	360	-
1 500 × 1 400	24,0	22,8	260	-
1 600 × 1 400	25,2	22,8	360	-
1 800 × 1 600	27,6	25,2	360	-
2 000 × 1 800	30,0	27,6	360	-

NOTE The larger end is designated DN and the smaller end is designated dn.

8.4 Fittings for flanged joints

8.4.1 General

In the following tables, all the dimensions are nominal values and are given in millimetres. For coatings and linings, see 4.5.

8.4.2 Double-flanged 90° (1/4) bends

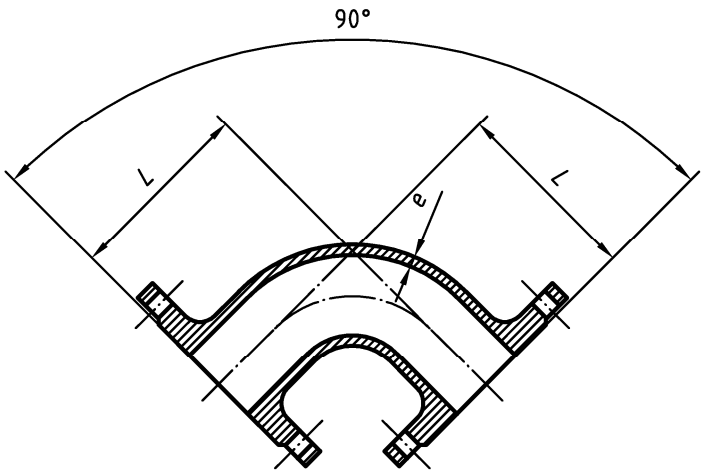


Figure 15

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8.4.3 Double-flanged duckfoot 90° (1/4) bends

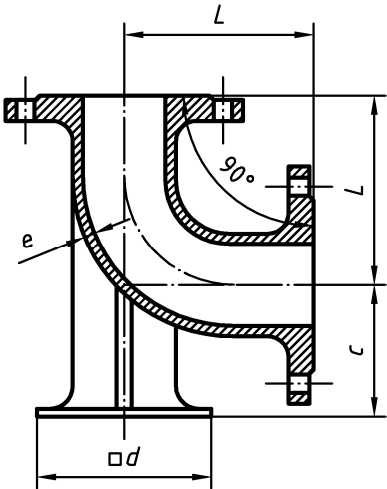


Figure 16

Table 25

DN	A and B series				
	e	90° (1/4) bends	90° (1/4) duckfoot bends		
		<i>L</i>	<i>L</i>	<i>c</i>	<i>d</i>
40	7,0	140	-	-	-
50	7,0	150	150	95	150
60	7,0	160	160	100	160
65	7,0	165	165	100	165
80	7,0	165	165	110	180
100	7,2	180	180	125	200
125	7,5	200	200	140	225
150	7,8	220	220	160	250
200	8,4	260	260	190	300
250	9,0	350	350	225	350
300	9,6	400	400	255	400
350	10,2	450	450	290	450
400	10,8	500	500	320	500
450	11,4	550	550	355	550
500	12,0	600	600	385	600
600	13,2	700	700	450	700
700	14,4	800	-	-	-
800	15,6	900	-	-	-
900	16,8	1 000	-	-	-
1 000	18,0	1 100	-	-	-

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8.4.4 Double-flanged 45° (1/8) bends

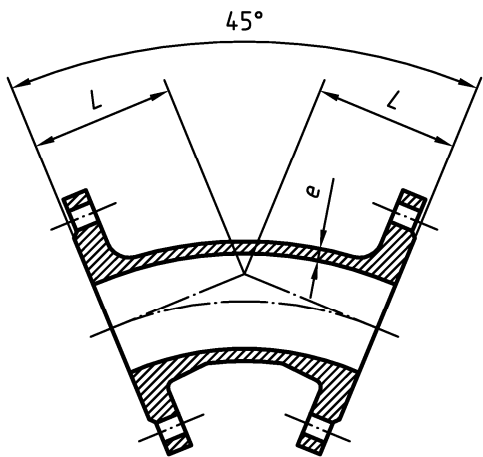


Figure 17

Table 26

DN	e	L series A	L series B
40	7,0	140	140
50	7,0	150	150
60	7,0	160	160
65	7,0	165	165
80	7,0	130	130
100	7,2	140	140
125	7,5	150	150
150	7,8	160	160
200	8,4	180	180
250	9,0	350	245
300	9,6	400	275
350	10,2	298	300
400	10,8	324	325
450	11,4	350	350
500	12,0	375	-
600	13,2	426	-
700	14,4	478	-
800	15,6	529	-
900	16,8	581	-
1 000	18,0	632	-
1 100	18,2	694	-
1 200	20,4	750	-
1 400	22,8	775	-
1 500	24,0	810	-
1 600	25,2	845	-
1 800	27,6	910	-
2 000	30,0	980	-

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8.4.5 Double-flanged 22°30' (1/16) bends

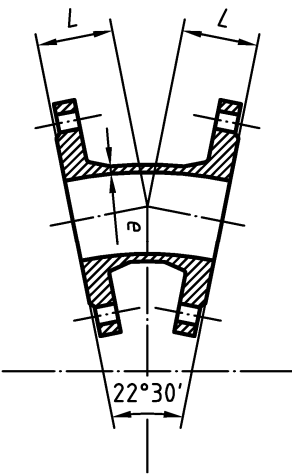


Figure 18

8.4.6 Double-flanged 11°15' (1/32) bends

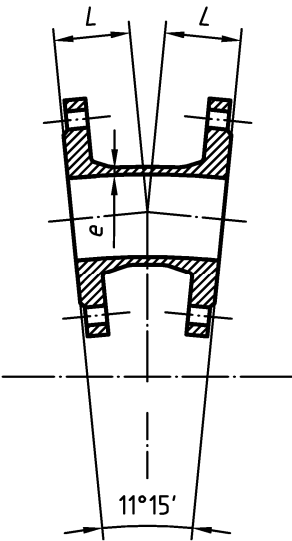


Figure 19

Table 27

DN	22°30' (1/16) bends			11°15' (1/32) bends		
	e	L series A	L series B	e	L series A	L series B
40	7,0	94	85	7,0	99	80
50	7,0	104	95	7,0	109	90
60	7,0	114	105	7,0	119	100
65	7,0	119	110	7,0	124	105
80	7,0	105	120	7,0	113	110
100	7,2	110	130	7,2	115	115
125	7,5	105	140	7,5	111	120
150	7,8	109	150	7,8	113	130
200	8,4	131	170	8,4	132	145
250	9,0	190	190	9,0	165	165
300	9,6	210	210	9,6	175	175
350	10,2	210	230	10,2	191	190
400	10,8	239	250	10,8	205	205
NOTE Double-flanged 22°30' and 11°15' bends of sizes larger than DN 400 are available, but with a range of effective lengths, depending on the manufacturer.						

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8.4.7 All-flanged tees, DN 40 to DN 250

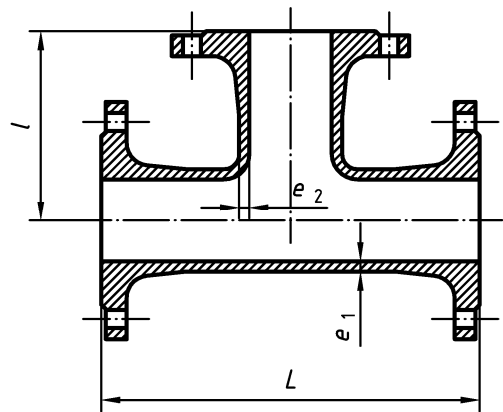


Figure 20

Table 28

DN × dn	Body			Branch		
	e ₁	L series A	L series B	e ₂	I series A	I series B
40 × 40	7,0	280	255	7,0	140	130
50 × 50	7,0	300	280	7,0	150	140
60 × 40	7,0	300	-	7,0	130	-
60 × 60	7,0	320	300	7,0	160	150
65 × 65	7,0	330	305	7,0	165	150
80 × 40	7,0	-	310	7,0	-	135
80 × 60	7,0	-	310	7,0	-	155
80 × 80	7,0	330	330	7,0	165	165
100 × 40	7,2	-	320	7,0		145
100 × 60	7,2	-	320	7,0		165
100 × 80	7,2	360	330	7,0	175	170
100 × 100	7,2	360	360	7,2	180	180
125 × 40	7,5	-	330	7,0	-	160
125 × 60	7,5	-	330	7,0	-	180
125 × 80	7,5	400	350	7,0	190	185
125 × 100	7,5	400	370	7,2	195	195
125 × 125	7,5	400	400	7,5	200	200
150 × 40	7,8	-	340	7,0	-	170
150 × 60	7,8	-	340	7,0	-	190
150 × 80	7,8	440	360	7,0	205	200
150 × 100	7,8	440	380	7,2	210	205
150 × 125	7,8	440	410	7,5	215	215
150 × 150	7,8	440	440	7,8	220	220
200 × 40	8,4	-	365	7,0	-	195
200 × 60	8,4	-	365	7,0	-	215
200 × 80	8,4	520	380	7,0	235	225
200 × 100	8,4	520	400	7,2	240	230
200 × 125	8,4	-	435	7,5	-	240
200 × 150	8,4	520	460	7,8	250	245
200 × 200	8,4	520	520	8,4	260	260
250 × 60	9,0	-	385	7,0	-	260
250 × 80	9,0	-	405	7,0	-	265
250 × 100	9,0	700	425	7,2	275	270
250 × 150	9,0	-	485	7,8	-	280
250 × 200	9,0	700	540	8,4	325	290
250 × 250	9,0	700	600	9,0	350	300

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn.

EN 545:2006 (E)**8.4.8 All-flanged tees, DN 300 to DN 700****Table 29**

DN × dn	Body			Branch		
	e ₁	L series A	L series B	e ₂	I series A	I series B
300 × 60	9,6	-	405	7,0	-	290
300 × 80	9,6	-	425	7,0	-	295
300 × 100	9,6	800	450	7,2	300	300
300 × 150	9,6	-	505	7,8	-	310
300 × 200	9,6	800	565	8,4	350	320
300 × 250	9,6	-	620	9,0	-	330
300 × 300	9,6	800	680	9,6	400	340
350 × 60	10,2	-	430	7,0	-	320
350 × 80	10,2	-	445	7,0	-	325
350 × 100	10,2	850	470	7,2	325	330
350 × 150	10,2	-	530	7,8	-	340
350 × 200	10,2	850	585	8,4	325	350
350 × 250	10,2	-	645	9,0	-	360
350 × 350	10,2	850	760	10,2	425	380
400 × 80	10,8	-	470	7,0	-	355
400 × 100	10,8	900	490	7,2	350	360
400 × 150	10,8	-	550	7,8	-	370
400 × 200	10,8	900	610	8,4	350	380
400 × 250	10,8	-	665	9,0	-	390
400 × 300	10,8	-	725	9,6	-	400
400 × 400	10,8	900	840	10,8	450	420
450 × 100	11,4	950	515	7,2	375	390
450 × 150	11,4	-	570	7,8	-	400
450 × 200	11,4	950	630	8,4	375	410
450 × 250	11,4	-	690	9,0	-	420
450 × 300	11,4	-	745	9,6	-	430
450 × 400	11,4	-	860	10,8	-	450
450 × 450	11,4	950	920	11,4	475	460
500 × 100	12,0	1 000	535	7,4	400	420
500 × 200	12,0	1 000	650	8,4	400	440
500 × 400	12,0	1 000	885	10,8	500	480
500 × 500	12,0	1 000	1000	12,0	500	500
600 × 200	13,2	1 100	700	8,4	450	500
600 × 400	13,2	1 100	930	10,8	550	540
600 × 600	13,2	1 100	1165	13,2	550	580
700 × 200	14,4	650	-	8,4	525	-
700 × 400	14,4	870	-	10,8	555	-
700 × 700	14,4	1 200	-	14,4	600	-

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn.

8.4.9 All-flanged tees, DN 800 to DN 2 000

Table 30

DN × dn	Body		Branch	
	e ₁	L series A	e ₂	I series A
800 × 200	15,6	690	8,4	585
800 × 400	15,6	910	10,8	615
800 × 600	15,6	1 350	13,2	645
800 × 800	15,6	1 350	15,6	675
900 × 200	16,8	730	8,4	645
900 × 400	16,8	950	10,8	675
900 × 600	16,8	1 500	13,2	705
900 × 900	16,8	1 500	16,8	750
1 000 × 200	18,0	770	8,4	705
1 000 × 400	18,0	990	10,8	735
1 000 × 600	18,0	1 650	13,2	765
1 000 × 1 000	18,0	1 650	18,0	825
1 100 × 400	19,2	980	8,4	795
1 100 × 600	19,2	1 210	13,2	825
1 200 × 600	20,4	1 240	13,2	885
1 200 × 800	20,4	1 470	15,6	915
1 200 × 1 000	20,4	1 700	18,0	945
1 400 × 600	22,8	1 550	13,2	980
1 400 × 800	22,8	1 760	15,6	1 010
1 400 × 1 000	22,8	2 015	18,0	1 040
1 500 × 600	24,0	1 575	13,2	1 035
1 500 × 1 000	24,0	2 040	18,0	1 095
1 600 × 600	25,2	1 600	13,2	1 090
1 600 × 800	25,2	1 835	15,6	1 120
1 600 × 1 000	25,2	2 065	18,0	1 150
1 600 × 1 200	25,2	2 300	20,4	1 180
1 800 × 600	27,6	1 655	13,2	1 200
1 800 × 800	27,6	1 885	15,6	1 230
1 800 × 1 000	27,6	2 120	18,0	1 260
1 800 × 1 200	27,6	2 350	20,4	1 290
2 000 × 600	30,0	1 705	13,2	1 310
2 000 × 1 000	30,0	2 170	18,0	1 370
2 000 × 1 400	30,0	2 635	22,8	1 430

NOTE The main nominal size is designated DN and the nominal size of the branch is designated dn

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8.4.10 Double-flanged tapers

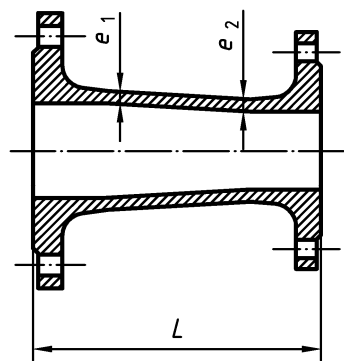


Figure 21

Table 31

DN × dn	e ₁	e ₂	L series A	L series B
50 × 40	7,0	7,0	150	165
60 × 50	7,0	7,0	160	160
65 × 50	7,0	7,0	200	190
80 × 60	7,0	7,0	200	185
80 × 65	7,0	7,0	200	190
100 × 80	7,2	7,0	200	195
125 × 100	7,5	7,2	200	185
150 × 125	7,8	7,5	200	190
200 × 150	8,4	7,8	300	235
250 × 200	9,0	8,4	300	250
300 × 250	9,6	9,0	300	265
350 × 300	10,2	9,6	300	290
400 3 300	10,8	9,6	300	-
400 × 350	10,8	10,2	300	305
450 × 400	11,4	10,8	300	320
500 × 400	12,0	10,8	600	-
600 × 500	13,2	12,0	600	-
700 × 600	14,4	13,2	600	-
800 × 700	15,6	14,4	600	-
900 × 800	16,8	15,6	600	-
1 000 × 900	18,0	16,8	600	-
1 100 × 1 000	19,2	18,0	600	-
1 200 × 1 000	20,4	18,0	790	-
1 400 × 1 200	22,8	20,4	850	-
1 500 × 1 400	24,0	22,8	695	-
1 600 × 1 400	25,2	22,8	910	-
1 800 × 1 600	27,6	25,2	970	-
2 000 × 1 800	30,0	27,6	1 030	-

NOTE The larger end is designated DN and the smaller end is designated dn.

EN 545:2006 (E)

8.4.11 Blank flanges PN 10

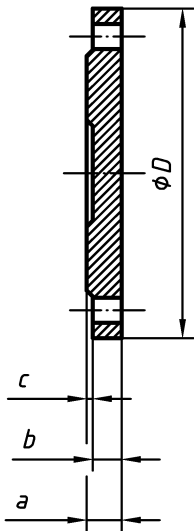


Figure 22

8.4.12 Blank flanges PN 16

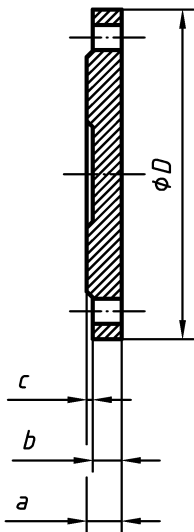


Figure 23

Table 32

DN	PN 10				PN 16			
	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i>
40	150	19	16	3	150	19	16	3
50	165	19	16	3	165	19	16	3
60	175	19	16	3	175	19	16	3
65	185	19	16	3	185	19	16	3
80	200	19	16	3	200	19	16	3
100	220	19	16	3	220	19	16	3
125	250	19	16	3	250	19	16	3
150	285	19	16	3	285	19	16	3
200	340	20	17	3	340	20	17	3
250	400	22	19	3	400	22	19	3
300	455	24,5	20,5	4	455	24,5	20,5	4
350	505	24,5	20,5	4	520	26,5	22,5	4
400	565	24,5	20,5	4	580	28	24	4
450	615	25,5	21,5	4	640	30	26	4
500	670	26,5	22,5	4	715	31,5	27,5	4
600	780	30	25	5	840	36	31	5
700	895	32,5	27,5	5	910	39,5	34,5	5
800	1 015	35	30	5	1 025	43	38	5
900	1 115	37,5	32,5	5	1 125	46,5	41,5	5
1 000	1 230	40	35	5	1 255	50	45	5
1 100	1 340	42,5	37,5	5	1 355	53,5	48,5	5
1 200	1 455	45	40	5	1 485	57	52	5
1 400	1 675	46	41	5	1 685	60	55	5
1 500	1 785	47,5	42,5	5	1 820	62,5	57,5	5
1 600	1 915	49	44	5	1 930	65	60	5
1 800	2 115	52	47	5	2 130	70	65	5
2 000	2 325	55	50	5	2 345	75	70	5

NOTE For blank flanges of nominal diameter greater than or equal to DN 300, the centre of blank flanges may be dished.

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8.4.13 Blank flanges PN 25

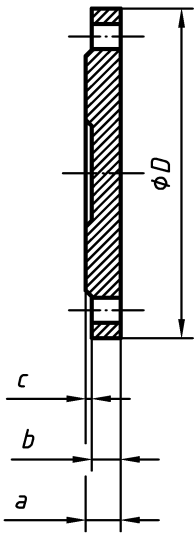


Figure 24

8.4.14 Blank flanges PN 40

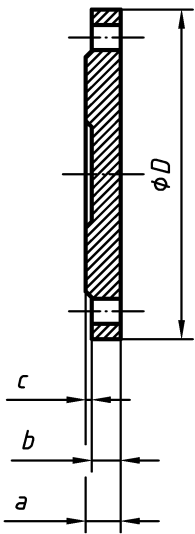


Figure 25

Table 33

DN	PN 25				PN 40			
	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i>
40	150	19	16	3	150	19	16	3
50	165	19	16	3	165	19	16	3
60	175	19	16	3	175	19	16	3
65	185	19	16	3	185	19	16	3
80	200	19	16	3	200	19	16	3
100	235	19	16	3	235	19	16	3
125	270	19	16	3	270	23,5	20,5	3
150	300	20	17	3	300	26	23	3
200	360	22	19	3	375	30	27	3
250	425	24,5	21,5	3	450	34,5	31,5	3
300	485	27,5	23,5	4	515	39,5	35,5	4
350	555	30	26	4	-	-	-	-
400	620	32	28	4	-	-	-	-
450	670	34,5	30,5	4	-	-	-	-
500	730	36,5	32,5	4	-	-	-	-
600	845	42	37	5	-	-	-	-
NOTE For blank flanges of nominal diameter greater than or equal to DN 300, the centre of blank flanges may be dished.								

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8.4.15 Reducing flanges PN 10

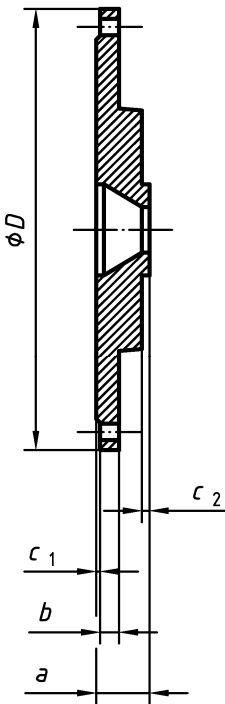


Figure 26

8.4.16 Reducing flanges PN 16

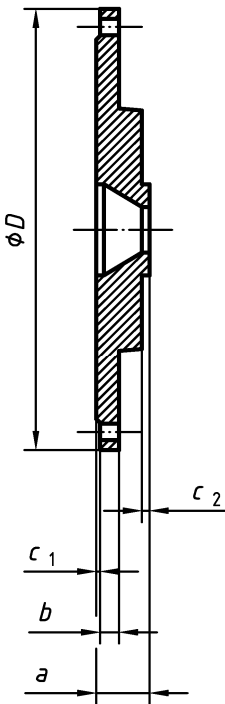


Figure 27

Table 34

DN × dn	PN 10					PN 16				
	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i> ₁	<i>c</i> ₂	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i> ₁	<i>c</i> ₂
200 × 80	340	40	17	3	3	340	40	17	3	3
200 × 100	340	40	17	3	3	340	40	17	3	3
200 × 125	340	40	17	3	3	340	40	17	3	3
350 × 250	505	48	20,5	4	3	520	54	22,5	4	3
400 × 250	565	48	20,5	4	3	580	54	24	4	3
400 × 300	565	49	20,5	4	4	580	55	24	4	4
700 × 500	895	56	27,5	5	4	910	67	34,5	5	4
900 × 700	1 115	63	32,5	5	5	1 125	73	41,5	5	5
1 000 × 700	1 230	63	35	5	5	1 255	73	45	5	5
1 000 × 800	1 230	68	35	5	5	1 255	77	45	5	5
NOTE The main nominal size is designated DN and the smaller nominal size is designated dn.										

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8.4.17 Reducing flanges PN 25

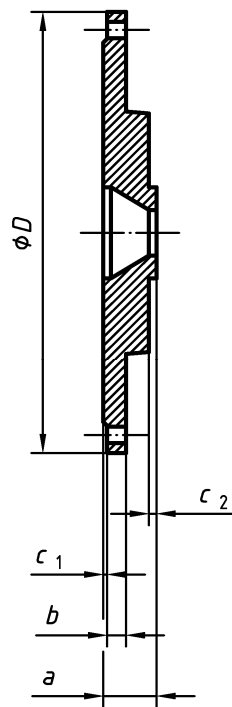


Figure 28

8.4.18 Reducing flanges PN 40

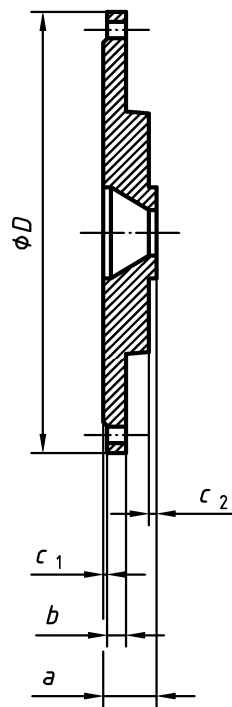


Figure 29

Table 35

DN × dn	PN 25					PN 40				
	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i> ₁	<i>c</i> ₂	<i>D</i>	<i>a</i>	<i>b</i>	<i>c</i> ₁	<i>c</i> ₂
200 × 80	360	40	19	3	3	375	40	27	3	3
200 × 100	360	47	19	3	3	375	47	27	3	3
200 × 125	360	53	19	3	3	375	53	27	3	3
350 × 250	555	60	26	4	3	-	-	-	-	-
400 × 250	620	60	28	4	3	-	-	-	-	-
400 × 300	620	61	28	4	4	-	-	-	-	-
NOTE The main nominal size is designated DN and the smaller nominal size is designated dn.										

EN 545:2006 (E)**Annex A**
(normative)**Allowable pressures****A.1 General**

The maximum values of PFA, PMA and PEA for pipes and fittings, as defined in 3.19, 3.20 and 3.21 respectively, shall be as given (in bars) in A.2, A.3 and A.4.

Appropriate limitations shall be taken into account which may prevent the full range of these pressures being used in an installed pipeline, for example:

- operation at the PFA and PMA values given in A.2 for socket and spigot pipes may be limited by the lower pressure capability of other pipeline components, e.g. flanged pipework (see A.4), certain types of tees (see A.3) and specific designs of flexible joints (see 5.2.2);
- site hydrostatic testing at the high PEA values given in A.2 may be limited by the type and design of the pipeline anchorage system and/or the design of flexible joints.

A.2 Socket and spigot pipes (see 8.1)

The maximum values of PFA, PMA and PEA as given in Table A.1 are calculated as follows:

- a) with a maximum of 64 bar for Class 40 pipes, and of 85 bar for Class K 9 and K 10 pipes,

$$PFA = \frac{20 \cdot e_{min} \cdot R_m}{D \cdot S_F}$$

where:

e_{min} is the minimum pipe wall thickness, in millimetres;

D is the mean pipe diameter (DE - e_{min}), in millimetres;

DE is the nominal pipe external diameter (see Table 15), in millimetres;

R_m is the minimum tensile strength of ductile iron, in megapascals ($R_m = 420$ MPa ; see 4.3.1);

S_F is a safety factor of 3.

- b) PMA : as PFA, but with $S_F = 2,5$; therefore

$$PMA = 1,2 \times PFA .$$

- c) PEA = PMA + 5 bar.

A.3 Fittings for socketed joints (see 8.3)

The maximum values of PFA, PMA and PEA are as follows:

- socketed fittings, except tees: their PFA, PMA and PEA are equal to those given in A.2 for K9 pipes;
- socketed tees: their PFA, PMA and PEA may be less than those given in A.2 for K9 pipes, they shall be given in the manufacturer's catalogues;
- fittings with one flange, such as double-socket tees with flanged branch, flanged spigots and flanged sockets: their PFA, PMA and PEA are limited by their flange; they are equal to those given in A.4 for the corresponding PN and DN.

When other limitations exist due to the joint type or to any specific design arrangement, they shall be given in the manufacturer's catalogues.

A.4 Flanged pipes (see 8.2) and fittings for flanged joints (see 8.4)

The maximum values for PFA, PMA and PEA are given in Table A.2.

EN 545:2006 (E)**Table A.1**

DN	Thickness class								
	Class 40			K9			K10		
	PFA	PMA	PEA	PFA	PMA	PEA	PFA	PMA	PEA
40	64	77	82	85	102	107	85	102	107
50	64	77	82	85	102	107	85	102	107
60	64	77	82	85	102	107	85	102	107
65	64	77	82	85	102	107	85	102	107
80	64	77	82	85	102	107	85	102	107
100	64	77	82	85	102	107	85	102	107
125	64	77	82	85	102	107	85	102	107
150	62	74	79	79	95	100	85	102	107
200	50	60	65	62	74	79	71	85	90
250	43	51	56	54	65	70	61	73	78
300	40	48	53	49	59	64	56	67	72
350	40	48	53	45	54	59	51	61	66
400	40	48	53	42	51	56	48	58	63
450	-	-	-	40	48	53	45	54	59
500	-	-	-	38	46	51	44	53	58
600	-	-	-	36	43	48	41	49	54
700	-	-	-	34	41	46	38	46	51
800	-	-	-	32	38	43	36	43	48
900	-	-	-	31	37	42	35	42	47
1 000	-	-	-	30	36	41	34	41	46
1 100	-	-	-	29	35	40	32	38	43
1 200	-	-	-	28	34	39	32	38	43
1 400	-	-	-	28	33	38	31	37	42
1 500	-	-	-	27	32	37	30	36	41
1 600	-	-	-	27	32	37	30	36	41
1 800	-	-	-	26	31	36	30	36	41
2 000	-	-	-	26	31	36	29	35	40
NOTE 1 See limitations given in A.1.									
NOTE 2 For thickness classes K10 and above, the maximum values of PFA, PMA and PEA are calculated in the same way and in this case a PFA limitation different from 85 bar may be agreed between manufacturer and purchaser.									

Table A.2

DN	PN 10			PN 16			PN 25			PN 40		
	PFA	PMA	PEA	PFA	PMA	PEA	PFA	PMA	PEA	PFA	PMA	PEA
40 to 50	See PN 40			See PN 40			See PN 40			40	48	53
60 to 80	See PN 16			16	20	25	See PN 40			40	48	53
100 to 150	See PN 16			16	20	25	25	30	35	40	48	53
200 to 600	10	12	17	16	20	25	25	30	35	40	48	53
700 to 1 200	10	12	17	16	20	25	25	30	35	-	-	-
1 400 to 2 000	10	12	17	16	20	25	-	-	-	-	-	-

Annex B (informative)

Longitudinal bending resistance of pipes

Pipes with an aspect ratio (length/diameter) equal to or greater than 25 may be subjected to high stresses due to bending moments caused for example by ground subsidence or by differential settlement.

In order to provide a high degree of safety in such situations, ductile iron pipes withstand the bending moments given in Table B.1, with no visible damage to the pipe wall and to the external and internal coatings. These bending moments have been calculated assuming a pipe of minimum wall thickness for its class and a bending stress in the metal equal to 250 MPa.

Table B.1

DN	Bending moments (kN·m)		
	Class 40	K9	K10
40	1,8	2,4	2,4
50	2,6	3,4	3,4
60	3,7	4,8	4,8
65	4,2	5,5	5,5
80	6,1	8,0	8,0
100	9,0	11,8	11,8
125	13,5	17,9	18,2
150	20,0	25,2	26,7
200	36,4	44,4	50,6

NOTE 1 These bending moments, expressed in kilonewton metres, correspond to a load of the same value, expressed in kilonewtons, applied at mid-point of a 4 m span.

NOTE 2 Bending moments that can cause failure of the pipes are at least 1,7 times higher than the given values.

EN 545:2006 (E)**Annex C**
(informative)**Diametral stiffness of pipes**

Ductile iron pipes can undergo large ovalizations in operation while keeping all their functional characteristics. Allowable pipe ovalizations, when the pipeline is in service, are given in Table C.1.

NOTE 1 The ovalization is one hundred times the vertical pipe deflection in millimetres divided by the initial pipe external diameter in millimetres.

In order to withstand large heights of cover and/or heavy traffic loads in a wide range of installation conditions, ductile iron pipes have the minimum diametral stiffness values given in Table C.1.

The diametral stiffness S of a pipe is given by the formula:

$$S = 1\,000 \frac{E \cdot I}{D^3} = 1\,000 \frac{E}{12} \left(\frac{e}{D} \right)^3 \quad (\text{C.1})$$

where:

S is the diametral stiffness, in kilonewtons per square metre;

E is the modulus of elasticity of the material, in megapascals (170 000 MPa);

I is the second moment of area of the pipe wall per unit length, in millimetres to the third power;

e is the wall thickness of the pipe, in millimetres;

D is the mean diameter of the pipe ($DE - e$), in millimetres;

DE is the nominal pipe external diameter, in millimetres.

NOTE 2 The values of S have been calculated assuming a pipe wall thickness equal to the minimum thickness plus half of the tolerance, in order to take account that there are only a few points with a thickness equal or close to the minimum thickness.

Table C.1

DN	Minimum diametral stiffness S kN/m ²			Allowable pipe ovalization %		
	Class 40	K9	K10	Class 40	K9	K10
40	7 000	16 500	16 500	0,60	0,45	0,45
50	4 200	9 500	9 500	0,70	0,55	0,55
60	2 600	5 500	5 500	0,85	0,65	0,65
65	2 100	4 800	4 800	0,90	0,70	0,70
80	1 200	2 700	2 700	1,10	0,85	0,85
100	680	1 500	1 500	1,30	1,05	1,05
125	370	810	880	1,60	1,30	1,20
150	250	480	600	1,85	1,55	1,40
200	130	230	340	2,25	1,90	1,70
250	91	160	220	2,60	2,20	2,00
300	68	110	160	2,90	2,50	2,25
350	67	89	120	2,95	2,70	2,45
400	63	72	100	3,00	2,90	2,60
450	-	61	86	-	3,05	2,75
500	-	52	74	-	3,25	2,90
600	-	41	58	-	3,55	3,20
700	-	34	49	-	3,75	3,40
800	-	30	42	-	4,00	3,55
900	-	26	37	-	4,00	3,75
1 000	-	24	34	-	4,00	3,85
1 100	-	22	31	-	4,00	4,00
1 200	-	20	29	-	4,00	4,00
1 400	-	18	26	-	4,00	4,00
1 500	-	17	24	-	4,00	4,00
1 600	-	17	23	-	4,00	4,00
1 800	-	16	22	-	4,00	4,00
2 000	-	16	21	-	4,00	4,00

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Annex D
(informative)

Alternative pipe coatings, field of use, characteristics of soils

D.1 Alternative pipe coatings

The following coatings may also be supplied, depending on the external and internal conditions of use :

a) External coatings:

- zinc rich paint coating having a minimum mass of 150 g/m², with finishing layer;
- thicker zinc coating having a minimum mass of 200 g/m², with finishing layer;
- polyethylene sleeve (as a supplement to the zinc coating with finishing layer);
- alloy of zinc and aluminium with or without other metals, having a minimum mass of 400 g/m², with finishing layer;
- extruded polyethylene coating in accordance with EN 14628;
- polyurethane coating in accordance with EN 15189;
- fibre reinforced cement mortar coating according to prEN 15542;
- adhesive tape.

b) Internal coatings (linings):

- bituminous paint lining;
- thicker cement mortar lining;
- cement mortar lining with seal coat;
- polyurethane lining.

c) Coating of the joint area:

- epoxy coating;
- polyurethane coating.

For the coatings for the joint area when agreed between the manufacturer and the purchaser, the upper limit deviation on the external diameter DE of the coated spigot may be greater than that specified in 8.1, provided that the interconnection of the products is ensured.

D.2 Field of use, characteristics of soils

D.2.1 Standard coating

Ductile iron pipes complying with 4.4.2 and ductile iron fittings and accessories complying with 4.5.2 may be buried in contact with a large number of soils, which can be identified by soil studies on site, except:

- soils with a low resistivity, less than 1500 $\Omega\cdot\text{cm}$ when laid above the water table or less than 2500 $\Omega\cdot\text{cm}$ when laid below the water table;
- mixed soils, i.e. comprising two or more soil natures;
- soils with a pH below 6 and a high reserve of acidity;
- soils containing refuse, cinders, slags or polluted by wastes or industrial effluents.

In such soils, and also in the occurrence of stray currents, it is recommended that an additional protection is used (such as polyethylene sleeving) or other types of external coatings as appropriate (see D.1 and 4.5.1).

D.2.2 Thicker zinc coating having a minimum mass of 200 g/m², with thicker finishing layer

An increase of the mass of the zinc coating (e.g. 200 g/m²) combined with a thicker finishing layer (e.g. $\geq 100\ \mu\text{m}$ polyurethane or epoxy) may extend the field of use to a resistivity of 1500 $\Omega\cdot\text{cm}$ when laid below the water table.

D.2.3 Alloy of zinc and aluminium with or without other metals

Ductile iron pipes coated with an alloy of zinc and aluminium with or without other metals having a minimum mass of 400 g/m² with finishing layer, together with ductile iron fittings coated with an electro-deposited coating having a minimum thickness of 50 μm and applied on a blast-cleaned and phosphated treated surface, or coated with an epoxy coating in compliance with EN 14901, may be buried in contact with the majority of soils, except:

- acidic peaty soils;
- soils containing refuse, cinders, slag, or polluted by wastes or industrial effluents;
- soils below the marine water table with a resistivity lower than 500 $\Omega\cdot\text{cm}$.

In such soils, and also in the occurrence of stray currents, it is recommended to use other types of external coatings adapted to the most corrosive soils (see D.1, D.2.4 and 4.5.1).

Evidence of the long term performance of the above mentioned solution (e.g. tests and references) should be provided by the manufacturer.

D.2.4 Reinforced coatings

Ductile iron pipes and fittings with the following external coatings may be buried in soils of all levels of corrosivity:

- extruded polyethylene coating (pipes) according to EN 14628;
- polyurethane coating (pipes) according to 15189;
- epoxy coating having a minimum average thickness of 250 μm (fittings) according to EN 14901;
- fibre reinforced cement mortar coating (pipes) according to prEN 15542;
- adhesive tapes (pipes and fittings).

Annex E
(informative)

Field of use, water characteristics

Ductile iron pipelines supplied with internal linings complying with 4.4.3 and 4.5.2 may be used to convey all types of water intended for human consumption in conformity with the Directive 98/83/EC.

For other types of water, the limits of use are as given in Table E.1, depending on the type of cement used for the lining.

Table E.1

Water characteristics	Portland cement	Sulphate resisting cements (including blast-furnace slag cements)	High alumina cement
Minimum value of pH	6	5,5	4
Maximum content (mg/l) of:			
Aggressive CO ₂	7	15	No limit
Sulphates (SO ₄ ⁻)	400	3 000	No limit
Magnesium (Mg ⁺⁺)	100	500	No limit
Ammonium (NH ₄ ⁺)	30	30	No limit

Annex F (informative)

Quality assurance

F.1 General

The manufacturer has the responsibility to demonstrate the conformity of his products with this standard by:

- carrying out performance tests (see F.2); and
- controlling the manufacturing process (see F.3).

F.2 Performance tests

The performance tests specified in Clauses 5 and 7 of this standard are carried out either by the manufacturer or, at his request, by a competent testing institute in order to demonstrate compliance with the requirements of this standard. Full reports of these performance tests are retained by the manufacturer as evidence of compliance.

F.3 Manufacturing process

F.3.1 Quality Control

The manufacturer controls the quality of his products during their manufacture by a system of process control in order to comply with the technical requirements of this standard. Wherever possible, statistical sampling techniques should be used.

It is recommended that the manufacturer's quality system conforms to EN ISO 9001.

If third party certification is involved, it is recommended that the certification body is accredited to EN 45011 or EN 45012, as applicable.

F.3.2 Tensile strength

During the manufacturing process the manufacturer carries out suitable tests in order to verify the tensile properties specified in 4.3.1. These tests may be:

- a) either a batch ¹⁾ sampling system whereby samples are obtained from the pipe spigot or, for fittings, from samples cast separately or integrally with the castings concerned. Test bars are machined from these samples and tensile tested in accordance with 6.3; or
- b) a system of process control (e.g. by non-destructive testing) where a positive correlation can be demonstrated with the tensile properties specified in Table 7. Testing verification procedures are based on the use of comparator samples having known and verifiable properties. This system is supported by tensile testing in accordance with 6.3.

The frequency of testing is related to the system of production and quality control used by the manufacturer. The maximum batch sizes shall be as given in Table F.1.

¹⁾ batch : quantity of castings from which a sample is taken for testing purposes during manufacture

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Table F.1

Type of casting	DN	Maximum batch size	
		Batch sampling system	Process control system
Centrifugally cast pipes	40 to 300	200 pipes	1 200 pipes
	350 to 600	100 pipes	600 pipes
	700 to 1 000	50 pipes	300 pipes
	1 100 to 2 000	25 pipes	150 pipes
Pipes not centrifugally cast, fittings and accessories	40 to 2 000	4t ^a	48t ^a
^a Weight of crude castings, excluding the risers.			

Annex G (informative)

Calculation method of buried pipelines, heights of cover

G.1 Calculation method

G.1.1 Calculation formula

The method is based on an ovalization calculation according to the formula below:

$$\Delta = \frac{100K (P_e + P_t)}{8S + (f \cdot E')} \quad (\text{G.1})$$

where:

Δ is the pipe ovalization (%);

K is the bedding factor;

P_e is the pressure from earth loading, in kilonewtons per square metre;

P_t is the pressure from traffic loading, in kilonewtons per square metre;

S is the pipe diametral stiffness, in kilonewtons per square metre, see Table C.1;

f is the factor of lateral pressure ($f = 0,061$);

E' is the modulus of soil reaction, in kilonewtons per square metre.

The ovalization calculated by means of this formula should not exceed the allowable ovalization shown in Table C.1. The allowable ovalization increases with DN while remaining well below the value that the internal cement mortar lining can withstand without damage; in addition, it provides a safety factor of 1,5 with respect to the elastic limit of ductile iron in bending (500 MPa minimum) by limiting the stress in the pipe wall at 330 MPa; finally, it is limited to 4 % for $\text{DN} \geq 800$.

G.1.2 Pressure from earth loading

The pressure P_e , uniformly distributed at the top of the pipe over a distance equal to the external diameter, is calculated according to the earth prism method by the formula below:

$$P_e = \gamma H \quad (\text{G.2})$$

where:

P_e is the pressure from earth loading, in kilonewtons per square metre;

γ is the unit weight of backfill, in kilonewtons per cubic metre;

H is the height of cover, in metres, that is the distance from the top of the pipe to the ground surface.

In the absence of other data, the unit weight of the soil is taken as being equal to 20 kN/m^3 in order to cover the vast majority of cases. If a preliminary geotechnical survey confirms that the actual unit weight of the backfill will be less than 20 kN/m^3 , the actual value may be used for determining P_e .

If, however, it appears that the actual value will be more than 20 kN/m^3 , the actual value should be used.

EN 545:2006 (E)**G.1.3 Pressure from traffic loading**

The pressure P_t , uniformly distributed at the top of the pipe over a distance equal to the external diameter, is calculated by means of the formula below:

$$P_t = 40 \cdot \left(1 - 2 \cdot 10^{-4} \cdot DN\right) \frac{\beta}{H} \quad (\text{G.3})$$

where:

P_t is the pressure from traffic loading in kilonewtons per square metre;

β is the traffic load factor.

This formula is not valid for $H < 0,3$ m.

Thereby three types of traffic loading are to be considered:

- traffic areas with main roads, $\beta = 1,5$: this is the general case of all roads, except access roads;
- traffic areas with access roads, $\beta = 0,75$: roads where lorry traffic is prohibited;
- rural areas, $\beta = 0,5$: all other cases.

It should be noticed that all pipelines should be designed for at least $\beta = 0,5$ even where they are not expected to be exposed to traffic loading. In addition, pipelines laid in the verge and embankment of roads should be designed to withstand the full traffic loading expected on these roads. Finally, for pipelines which may be exposed to particularly high traffic loading, a factor $\beta = 2$ should be adopted.

G.1.4 Bedding factor, K

The bedding factor K , depends upon the soil pressure distribution at the top of the pipe (over a distance equal to the external diameter) and at the invert of the pipe (over a distance corresponding to the theoretical bedding angle 2α).

K normally varies from 0,11 for $2\alpha = 20^\circ$ to 0,09 for $2\alpha = 120^\circ$. The value of 20° corresponds to a pipe which is simply laid on the flat trench bottom, with no compaction effort.

G.1.5 Factor of lateral pressure, f

The factor of lateral pressure f , is equal to 0,061; this corresponds to a parabolic distribution of the lateral soil pressure over an angle of 100° , according to the IOWA-Spangler model.

G.1.6 Modulus of soil reaction, E'

The modulus of soil reaction E' depends upon the nature of soil used in the pipe zone and upon the laying conditions.

In a given situation, the modulus of reaction which is required can be determined by means of the formula below:

$$E' = \frac{4000K}{\delta \cdot f} \left(\frac{\beta}{H} \left(1 - 2 \cdot 10^{-4} DN\right) + 0,5 H \right) - \frac{8 S}{f} \quad (\text{G.4})$$

where:

E' is the modulus of soil reaction, in kilonewtons per square metre;

δ is the allowable ovalization, in %.

In Tables G.1 and G.2, values of E' equal to 1 000 kN/m², 2 000 kN/m² and 5 000 kN/m² are taken as guidelines; they correspond to a compaction level which is respectively nil, low and good. The value $E' = 0$ has also been shown as the limit case for unfavourable laying conditions in poor soils (no compaction, water table above the pipe, trench shoring removed after backfilling or embankment conditions).

If a preliminary geotechnical survey allows the determination of the value of the modulus of soil reaction, this value should be taken into account in the calculations.

G.2 Heights of cover

Tables G.1 and G.2 give the most pessimistic range of values of the allowable heights of cover for each group of diameters. These values can be used without any additional calculation: they are given in metres, with E' in kilonewtons per square metre.

For heights of cover outside the ranges given in Tables G.1 and G.2, and for other laying conditions, verification can be made using the formulae given in G.1.

EN 545:2006 (E)**Table G.1 - K9 pipes**

DN		40 to 200	250 and 300	350 to 450	500 to 2 000
$K(2\alpha)$		0,110 (20°)	0,110 (20°)	0,105 (45°)	0,103 (60°)
$\beta = 0,50$ Rural areas	$E' = 0$	0,3 to 15,4	0,3 to 9,9	0,3 to 6,9	0,3 to 2,2
	$E' = 1\ 000$	0,3 to 15,9	0,3 to 10,6	0,3 to 7,8	0,3 to 3,5
	$E' = 2\ 000$	0,3 to 16,4	0,3 to 11,3	0,3 to 8,7	0,3 to 4,7
	$E' = 5\ 000$	0,3 to 17,9	0,3 to 13,4	0,3 to 11,4	0,3 to 8,3
$\beta = 0,75$ Access roads	$E' = 0$	0,3 to 15,3	0,3 to 9,8	0,3 to 6,8	0,5 to 2,0
	$E' = 1\ 000$	0,3 to 15,8	0,3 to 10,5	0,3 to 7,7	0,3 to 3,4
	$E' = 2\ 000$	0,3 to 16,4	0,3 to 11,2	0,3 to 8,7	0,3 to 4,6
	$E' = 5\ 000$	0,3 to 17,9	0,3 to 13,3	0,3 to 11,3	0,3 to 8,2
$\beta = 1,50$ Main roads	$E' = 0$	0,3 to 15,2	0,3 to 9,7	0,4 to 6,6	^a
	$E' = 1\ 000$	0,3 to 15,8	0,3 to 10,4	0,4 to 7,6	0,6 to 3,0
	$E' = 2\ 000$	0,3 to 16,3	0,3 to 11,1	0,3 to 8,5	0,5 to 4,4
	$E' = 5\ 000$	0,3 to 17,8	0,3 to 13,2	0,3 to 11,2	0,3 to 8,1

^a Not recommended; only a specific calculation for each case can provide an adequate answer.

NOTE The values given for the heights of cover have been established for the class K9; they are also valid for classes $K \geq 10$.

Table G.2 - Class 40 pipes

DN		40 to 200	250 and 300	350 and 400
$K(2\alpha)$		0,110 (20°)	0,110 (20°)	0,105 (45°)
$\beta = 0,50$ Rural areas	$E' = 0$	0,3 to 10,5	0,3 to 7,0	0,3 to 7,1
	$E' = 1\ 000$	0,3 to 11,1	0,3 to 7,8	0,3 to 8,0
	$E' = 2\ 000$	0,3 to 11,8	0,3 to 8,6	0,3 to 8,9
	$E' = 5\ 000$	0,3 to 13,6	0,3 to 11,1	0,3 to 11,60
$\beta = 0,75$ Access roads	$E' = 0$	0,3 to 10,4	0,3 to 6,9	0,3 to 7,0
	$E' = 1\ 000$	0,3 to 11,1	0,3 to 7,7	0,3 to 7,9
	$E' = 2\ 000$	0,3 to 11,7	0,3 to 8,6	0,3 to 8,8
	$E' = 5\ 000$	0,3 to 13,6	0,3 to 11,0	0,3 to 11,5
$\beta = 1,50$ Main roads	$E' = 0$	0,3 to 10,3	0,5 to 6,7	0,5 to 6,8
	$E' = 1\ 000$	0,3 to 10,9	0,4 to 7,6	0,4 to 7,8
	$E' = 2\ 000$	0,3 to 11,6	0,4 to 8,4	0,4 to 8,7
	$E' = 5\ 000$	0,3 to 13,5	0,3 to 10,9	0,3 to 11,4

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